No. 205. Vol. XXXV. JANUARY, 1888.

Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN

JOURNAL OF SCIENCE.

EDITORS
JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS
PROFESSORS ASA GRAY, JOSIAH P. COOKE, AND JOHN TROWBRIDGE, OF CAMBRIDGE,

PROFESSORS H. A. NEWTON AND A. E. VERRILL, OF NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XXXV.—[WHOLE NUMBER, CXXXV.]

No. 205—JANUARY, 1888.

WITH PLATE I.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1888.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

LITTELL'S LIVING AGE.

IN 1888 **THE LIVING AGE** enters upon its forty-fifth year, having met with constant commendation and success.

A WEEKLY MAGAZINE, it gives fifty-two numbers of sixty-four pages each, or more than **Three and a Quarter Thousand** double-column octavo pages of reading-matter yearly. It presents in an inexpensive form, considering its great amount of matter, with freshness, owing to its weekly issue, and with a completeness nowhere else attempted,

The best Essays, Reviews, Criticisms, Serial and Short Stories, Sketches of Travel and Discovery, Poetry, Scientific, Biographical, Historical, and Political Information, from the entire body of Foreign Periodical Literature, and from the pens of

The Foremost Living Writers.

The ablest and most cultivated intellects, in every department of Literature, Science, Politics, and Art, find expression in the Periodical Literature of Europe, and especially of Great Britain.

The Living Age, forming four large volumes a year, furnishes from the great and generally inaccessible mass of this literature, the only compilation that, while within the reach of all, is satisfactory in the COMPLETENESS with which it embraces whatever is of immediate interest, or of solid, permanent value.

It is therefore indispensable to every one who wishes to keep pace with the events or intellectual progress of the time, or to cultivate in himself or his family general intelligence and literary taste.

OPINIONS.

"We have thought that it was impossible to improve upon this grand publication, yet it does seem to grow better each year. . We regard it as the most marvellous publication of the time. . Nowhere else can be found such a comprehensive and perfect view of the best literature and thought of our times. . It is unapproachable by any other publication of its kind, and is in itself a complete library of current literature, while all the leading topics of the day are touched and discussed by the best pens of the age. . No inducement could prevail upon those who have once become familiar with it to do without its regular visits."— *Christian at Work, New York.*

"By reading it one can keep abreast of the current thought upon all literary and public matters. It maintains its leading position in spite of the multitude of aspirants for public favor. . A grand repository of the literature of the age."— *New-York Observer.*

"Such a publication exhausts our superlatives. . There is nothing noteworthy in science, art, literature, biography, philosophy, or religion, that cannot be found in it. . It contains nearly all the good literature of the time."— *The Churchman, New York.*

"The more valuable to a man the longer he takes it. He comes to feel that he cannot live without it."— *New-York Evangelist.*

"To have THE LIVING AGE is to hold the keys of the entire world of thought, of scientific investigation, psychological research, critical note, of poetry and romance."— *Boston Evening Traveller.*

"Fiction, biography, science, criticism, history, poetry, art, and, in the broader sense, politics, enter into its scope, and are represented in its pages. . Nearly the whole world of authors and writers appear in it in their best moods. . The readers miss very little that is important in the periodical domain."— *Boston Journal.*

"The American reader who wishes to keep the run of English periodical literature can do so in no other way so thoroughly and cheaply as by taking THE LIVING AGE."— *Springfield Republican.*

"Through its pages alone it is possible to be as well informed in current literature as by the perusal of a long list of monthlies."— *Philadelphia Inquirer.*

"Foremost of the eclectic periodicals."— *New-York World.*

"There has been a vast development of literature in cheap and convenient forms of late; but so far as we know none has arisen which can take the place of THE LIVING AGE. All branches of literary activity are represented in it. . In reading its closely printed pages one is brought in contact with the men who are making opinion the world over. . Always new, always attractive, always exhibiting editorial wisdom, it is as essential as ever to every one desirous of keeping up with the current of English literature."— *Episcopal Recorder, Philadelphia.*

"It stands unrivalled, collecting the best thought of the day, and spreading it before its readers with a wonderful power of selection. . The ablest essays and reviews of the day are to be found here."— *The Presbyterian, Philadelphia.*

"It may be truthfully and cordially said that it never offers a dry or valueless page."— *New-York Tribune.*

"It is edited with great skill and care, and its weekly appearance gives it certain advantages over its monthly rivals."— *Albany Argus.*

"For a great deal of good literature for a little money THE LIVING AGE leads the periodicals. . It occupies a place of eminence from which no rival can crowd it."— *Troy Times.*

"It saves much labor for busy people who have no time to go over the various reviews and magazines, but who still wish to keep themselves well informed upon the questions of the day."— *The Advance, Chicago.*

"It furnishes a complete compilation of an indispensable literature."— *Chicago Evening Journal.*

"At its publication price it is the cheapest reading one can procure."— *Boston Globe.*

"It has been our literary companion for many years, and it furnishes us with a literary *pabulum* — historical, scientific, philosophical, philological, and critical — found nowhere else in the wide domain of literature."— *Christian Leader, Cincinnati.*

"It enables its readers to keep fully abreast of the best thought and literature of civilization."— *Christian Advocate, Pittsburg.*

"It is unequalled."— *North Carolina Presbyterian, Wilmington.*

"It is absolutely without a rival."— *Montreal Gazette.*

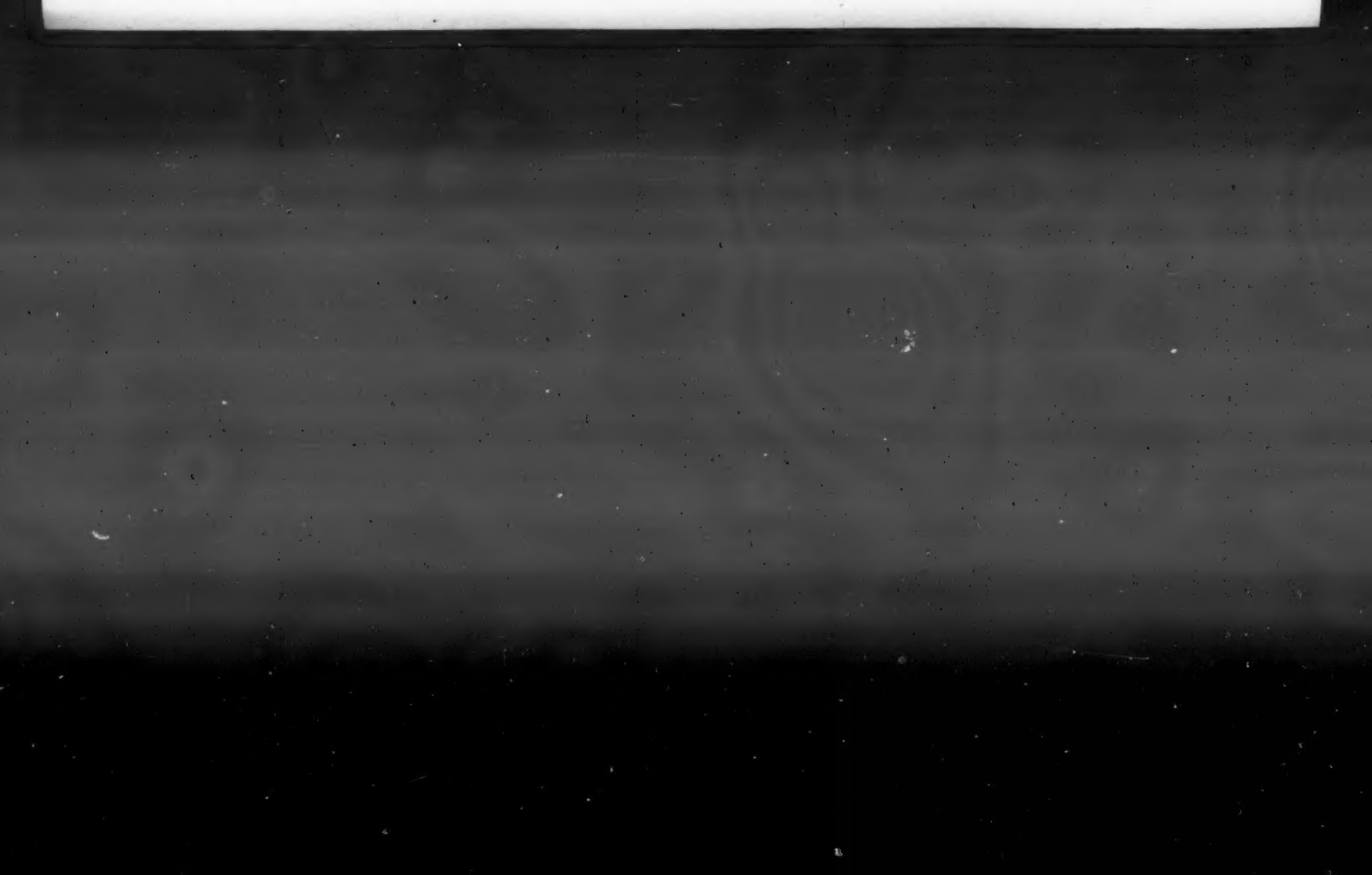
PUBLISHED WEEKLY at $8.00 a year, *free of postage.*

CLUB PRICES FOR THE BEST HOME AND FOREIGN LITERATURE.

["Possessed of LITTELL'S LIVING AGE, and of one or other of our vivacious American monthlies, a subscriber will find himself *in command of the whole situation.*"— *Philadelphia Evening Bulletin.*]

For $10.50, THE LIVING AGE and any one of the *four-dollar* monthly magazines (or *Harper's Weekly* or *Bazar*) will be sent for a year, with postage prepaid on both; or, for $9.50, THE LIVING AGE and the *St. Nicholas* or *Scribner's Magazine*, postpaid.

ADDRESS **LITTELL & CO., 31 Bedford St., Boston.**



THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. I.—*The Speed of Propagation of the Charleston Earthquake;* discussed by Professor SIMON NEWCOMB, U. S. N., and Captain C. E. DUTTON, U. S. A.

THE investigation of the time data of the Charleston earthquake having been completed and a final result being reached, it is deemed proper, with the consent of the Director of the Geological Survey, to publish a brief abstract of the discussion. The full discussion will appear in the final report upon the earthquake, which report is now well advanced toward completion.

Immediately after the earthquake all practicable measures were taken to collect information, and special effort was directed to obtaining the largest amount of time data. Through the courtesy of the Associated Press, notices were published in nearly all the newspapers of the country requesting those who had made such observations to forward them to the Director of the Geological Survey. Many persons did so. The Chief Signal Officer instructed the observers of that bureau who had noted the time of the shock to report it, and he forwarded all such reports to the survey. The Western Union Telegraph Co. instructed its operators to forward reports and similar instructions were sent by the Lighthouse Board to light-keepers. Special effort was made to secure newspapers from as many localities as possible. Most of the leading papers of the

country have an agent or reporter at Washington and he usually keeps a file of the paper he serves. The library of Congress keeps files of two or more papers from every State. As many of these as practicable were thoroughly examined. Many local papers were requested to furnish copies of their issues of Sept. 1st, 2d and 3d, and most of them complied. Many marked copies of papers were sent to the survey from unexpected sources. Altogether more than four hundred time reports were gathered.

As might be expected a portion of these were useless. In order that it may be apparent which were selected for consideration and which rejected, the following account is given. There were about thirty which stated that the shock occurred "about 10 o'clock" or "a few minutes before 10." As a single minute is a very important quantity here, all such reports were summarily rejected as too indefinite. The reports from lighthouses in most cases proved unavailable. These structures being situated most frequently where access to standard time is difficult, their clocks are regulated by the sun and an almanac. The uncertainties of this method of time keeping were evidently too great to justify any attempt to utilize them. But a few lighthouses keep standard time and in all such cases their reports were admitted to consideration. There were a few (nine or ten) which gave times so widely aberrant, differing by a quarter to half an hour from the great mass of records, that they were rejected. The whole number which received preliminary consideration was 316, many of which it was expected would also be rejected after a more thorough examination, due cause being assigned. These 316 observations were catalogued in alphabetical order, the latitudes and longitudes of the localities being roughly ascertained and also their distance from the centrum.

By far the most important time determination is that of the centrum, which was computed to be about six seconds earlier than that of Charleston. The time at Charleston is derived as follows. Among the numberless clocks stopped in that city by the earthquake, there were four which had compensated seconds pendulums and second hands and were of the pattern generally classed as "jewelers' regulators." All were compared daily with the time signal of the Western Union Telegraph Co., and the testimony is positive that none of them had errors on August 31st exceeding nine seconds, while the mean probable error of the four was certainly much less than this. The first was the regulator of James Allan & Co., Jewelers, No. 285 King street. It was regulated by means of a "sounder," which was daily put into circuit with the Western Union time signal wire. The clock was corrected only when its error exceeded

nine seconds. Mr. Allan is authority for the statement that its reading next morning was 9:51 exactly. He had received the time signal on August 31st, but as the clock was within the limit of tolerance he did not correct it. Subject to this limit he had no knowledge of the exact error of his clock and his memory on this point did not serve him The second clock was the regulator which controls the time of the North Eastern Railway. This clock was compared with the time signal on August 31st, but was not corrected, its error being within the limit of tolerance, which was eight seconds. It had been reset two days previously. Its reading was 9:51:15. It was stopped by the point of the pendulum catching behind the metallic arc in front of which it properly vibrates. The third clock was that which regulates the time of the Charleston & Savannah Railroad. It had been reset two days previously and compared with the time signal on August 31st, and was within the limit of tolerance, eight seconds. Its reading was 9:51:16 and it was stopped in the same manner as the preceding one. The fourth clock was that of the South Carolina Railroad. It had been reset by the daily time signal on the day of the earthquake. Its reading was 9:51:48.

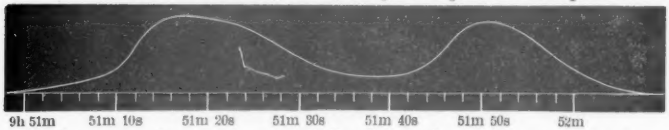
Although these records range through an interval of 48 seconds they may be reconciled. The azimuths of the planes of oscillation of their pendulums were as follows:

James Allan & Co's	N. 85° E.
North Eastern Railroad	N. 40° E.
Charleston & Savannah Railroad	N. 66° E.
South Carolina Railroad	N. 30° W.

These azimuths may be put into relation with what is now known concerning the varying phases of the shocks, their respective durations and directions of vibratory motion. The earthquake at Charleston began as a light tremor, steadily increasing in power through an interval estimated to be from 10 to 15 seconds' duration; then suddenly or by swift degrees it swelled into the full power of the first maximum, then subsided to a minimum, then swelled suddenly to a second maximum and lastly died away gradually. The interval from the beginning of the first maximum to the close of the second maximum is estimated at from 35 to 55 seconds; the subsiding tremors are estimated at about 6 to 8 seconds: the total duration from 55 to 75 seconds. It may be expressed graphically by the following curve in which the abscissas represent time and the ordinates an arbitrary scale of intensity.

In the first maximum the waves were mainly normal and came from N. 30° W. In the second maximum the direction of vibration was about at right angles with the foregoing or

about N. 60° E. It will now be seen that the planes of oscillation of the first three clocks made wide angles with the direction of motion of the first maximum, while the plane of the fourth clock was almost exactly parallel with that direction and perpendicular to the direction of motion of the second maximum. The fourth clock, then, may easily have escaped arrest



until the second maximum while the other three would have little chance of escaping the first maximum, even if they did not stop during the lighter preliminary tremors. That the second and third clocks stopped during the first maximum is rendered probable by the way in which their pendulums were caught. It would require a considerable acceleration in a direction perpendicular to their planes of oscillation and at times when the pendulums were near the extremities of their arcs of vibration in order to throw their bobs far enough backward to catch in the manner they did. These two clocks are relied upon as giving the time of the first maximum. The chances are, however, that the pendulums were not caught in this particular way during the first three or four oscillations, but went staggering along for a very few beats until finally caught. An interval of three or four seconds was probably occupied in the rapid swelling of the quake from the preliminary milder phase into the full power of the maximum. If we assume for the beginning of the first maximum an instant of time about three or four seconds earlier than that indicated by the two railroad clocks, i. e. 9:51:12, our actual error, it is believed will not exceed four seconds. The clock of James Allan & Co. probably stopped at a slightly earlier phase. If it may be assumed to have been six or eight seconds slow, its stopping would have been easily possible at that phase; for many less sensitive clocks throughout the country were arrested by tremors no more forcible than those in Charleston at the particular phase thus indicated. We shall reach the same result, 9:51:12, if we throw out the fourth clock as relating to the second maximum and (giving the weight 2 to both the second and third clocks and the weight 1 to the first) take the mean readings of the three. The whole tenor of the evidence from other clocks in Charleston points strongly to a time a few seconds later than 9:51 for the first maximum.

It is plainly necessary to select some phase of the earthquake in Charleston or at the centrum as the beginning, with which the beginning in all other places must be compared. It must

plainly be a phase at which the shocks had very great power, sufficient to make themselves felt hundreds of miles away. This phase should obviously be that which has been called the beginning of the first maximum. It still remains to find the corresponding time at the centrum. As the speed of propagation is now known to have been in the neighborhood of three miles a second and as the distance of Charleston from the theoretic centrum is 20 miles, the subtraction for the time at the centrum is taken to be six seconds, making the time of beginning at that point 9:51:06 standard time of the 75th meridian.

The full catalogue was next examined in order to ascertain what reports should be finally rejected. In the final report this catalogue will be published, together with a list of the rejected observations showing the grounds of rejection. For present purposes a summary view of these reports is given, showing the number of observations corresponding to specific minutes or falling betweeen consecutive minutes.

Table showing the numbers of reports corresponding to specified minutes or falling between consecutive minutes.

9:47 and seconds	1
9:48	3
9:50	32
9:51	6
9:51 and seconds	6
9:52	25
9:52 and seconds	9
9:53	28
9:53 and seconds	16
9:54	31
9:54 and seconds	9
9:55	86
9:55 and seconds	8
9:56	21
9:56 and seconds	2
9:57	8
9:58	5
9:58 and seconds	1
9:59	3
10:00	13
10:01	2
10:02	1
Total	316

There are thus four reports giving times earlier than 9:50 and three later than 10 o'clock. The synopsis illustrates well the tendency of people to give time in terms which are multiples

of five minutes. Thus we have 32 giving 9:50, but none giving 9:49, and only six giving 9:51. There are 13 giving 10 o'clock and there would have been many more of them if the catalogue had included those which stated the time as being "about" 10 o'clock or "near" 10 o'clock. There are 86, or more than one fourth the whole number, which give 9:55. Every one of the 9:50 reports is rejected. It is certain that they all involve errors greater than one minute too early, and the large number of them would introduce a large systematic error into the mean; and as there is no apparent reason for rejecting or keeping one observation rather than another, all of them are thrown out. All of the 10 o'clock observations are thrown out. For, upon further examination, all giving 9:58 and seconds, 9:59, 10:01 and 10:02 will be rejected on their merits. This would leave the 10 o'clock reports as an isolated group in an otherwise comparatively orderly series, and its effect would be to introduce an error of unknown magnitude and of anomalous character. In dealing with those giving 9:55 there is more difficulty. The following course has been adopted. Wherever a report states clearly, or raises a strong presumption, that this was really the nearest minute observed, to the exclusion of any other, it is accepted if otherwise unobjectionable. Where this evidence is wanting the report is rejected. It is quite probable that some thus rejected are very good observations; but it is clearly better to reject many possibly good observations (provided a sufficient number remain) than to admit a few bad ones with the certainty of introducing an unknown error. The number of 9:55 reports thus rejected is 43, which happens to be just one half.

Still other observations are rejected on their merits. A majority of these are thrown out for what are presumed to be large unexplained errors. There are 29 of them, of which 15 are rejected for being two minutes or more too early and 14 for being as much, or more than as much, too late, when compared with a larger number of much better observations in the same locality or in the immediately surrounding region. The rejection of these 29 observations does not greatly affect the deduced speed, but it does diminish notably the computed probable error. The total number rejected for all causes is 130 and the number accepted is 186. These have been separated into four groups, each containing data which are considered to be as nearly homogeneous as possible; that is to say, in each group the observations are presumed to have the same sources of error, whether accidental or systematic.

The first group is required to fulfill the following conditions: (1) The report must specify the beginning, or the time when the tremors first became sensible. (2) It must give not

only the minutes, but also the seconds, with an uncertainty not exceeding 15 seconds. (3) It must have been obtained from a clock kept running with accuracy upon standard time or equally reliable local time, or from a clock or watch compared with such time within a few hours of the occurrence. There are five observations besides that of Charleston which meet these requirements.

The second group will consist of those which fulfill the same conditions as the first, except that they will be required to give only the minute or half minute nearest to the beginning. There are eleven which answer to these requirements.

The third group will include all that remain after taking out groups I, II, and the stopped clocks. Some of these state that the time is that of the beginning, but fail to show that any attempt was made to ascertain the error of the time-piece. Some give a satisfactory account of the time-piece, but fail to state the phase to which the reported time refers. Many do neither the one nor the other. The number of reports in this group is 125.

The fourth group consists of accepted reports of clocks stopped by the first great shock. The clocks, however, must be stated to have been regulated carefully by standard time or by local time known to be equally accurate.

In all the groups there is more or less discordance among the several observations, no two giving the same speed. As the errors of the first two groups are believed to be mainly of the accidental class, the best method seems to be to submit them to the process of least squares. The equations of condition may be formed very simply in the following manner: The computed time of the beginning at the centrum (which has already been given) must be presumed to have some error, which may be designated by x. If t_0 be the computed time at the centrum (9:51:06) and t the reported time at any other locality, then $(t-t_0)$ = the number of seconds in the observed time-interval taken by the wave to travel from the centrum to the place of observation. If D be the distance in statute miles, and y the number of seconds or fraction of a second required to travel one mile, we may form the following equation: $x+Dy=t-t_0$, in which there are only two unknown quantities, x and y. This implies that the speed is uniform. If this implication differs widely from the truth, indications of it may be expected to appear in the residuals. It is necessary to put the equations of condition into a form in which a time and not a speed shall be the unknown quantity, because the times and not the distances are the data into which the greatest uncertainty enters. If, putting v for the speed of transmission, we put our equations into the form of $v(t-t_0)=D$, they would be subject to the objection that their uncertain quantities would be the coeffi-

cients of the unknown quantities and not the absolute terms. The distances from the centrum have been taken from the Land Office map of the United States by measurement with a scale. They are subject to possible errors as great as three or four miles, but this error is so small in comparison with the best times that the distances may be regarded as sensibly exact.

The following reports constitute the first group. For the sake of brevity the full accounts of these reports are here omitted. They will appear in the final work on the earthquake.

GROUP I.—*The best Observations.*

Locality.	State.	Distance.	Time 9h+ m.	s.	Weight.	Observer.
Centrum,	S. C.	0	51	06	2	
Washington,	D. C.	452	53	20	2	Prof. Newcomb
Washington,	D. C.	452	53	23	2	Alex. McAdie.
Baltimore,	Md.	487	53	20	1	R. Randolph.
New York,	N. Y.	645	54	30	2	M. C. Whitney.
Dyersburg,	Tenn.	569	54	00	1	Louis Hughes.

From these observations the following equations of condition may be formed.

	Wt.	Resid.
$x + 0y = 0$	2	$-2{\cdot}6$
$x + 452y = 135{\cdot}5$	4	$+1{\cdot}6$
$x + 487y = 134$	1	$+13{\cdot}9$
$x + 569y = 174$	1	$-0{\cdot}8$
$x + 645y = 204$	2	$-7{\cdot}3$

By the process of least squares the normal equations are:

$$10x + 4154 = 1258$$
$$4154x + 2210196 = 672408$$

The solution is, $x = -2{\cdot}6\text{s.} \pm 4{\cdot}7\text{s.}$ and $y = 0{\cdot}309 \pm 0{\cdot}01$. The resulting speed is, $3{\cdot}236 \pm 0{\cdot}105$ miles or 5205 ± 168 meters per second.

GROUP II.—*Good reports, giving the time of beginning to the nearest minute or half minute.*

Locality.	State.	Distance.	Time.	Weigh	Observer.
Centrum,	S. C.	0	51^m06^s	2	
Nashville,	Tenn.	438	53 30	1	J. D. Leonard.
Covington,	Ky.	488	53 41	1	Jos. Brookshaw.
Pikesville,	Md.	490	53 30	1	C. R. Goodwin.
Evansville,	Ind.	545	54	1	F. W. Norton.
Cleveland,	O.	604	54	1	Wm. Line.
Cleveland,	O	604	54	1	G. H. Tower.
Crawfordsville,	Ind.	620	54	½	E. C. Simpson.
Belvidere,	N. J.	622	54	1	G. W. Holstein.
New York,	N. Y.	645	54 30	1	N. Y. Herald.
Stockbridge,	Mass.	765	56	½	J. O. Jacot.
Albany,	N. Y.	770	55	1	W. G. Tucker.

From these we may form the following equations.

	Weight.	Residuals.
$x + 0y = 0$	2	− 1·6
$x + 438y = 144$	1	− 9·8
$x + 488y = 155$	1	− 5·3
$x + 490y = 144$	1	+ 6·3
$x + 545y = 174$	1	− 6·6
$x + 604y = 174$	2	+11·6
$x + 620y = 174$	½	+16·6
$x + 622y = 174$	1	+17·2
$x + 645y = 204$	1	− 5·6
$x + 765y = 294$	½	−58·4
$x + 770y = 234$	1	+ 3·1

The normal equations are:

$$12\,x + 5898{\cdot}5\,y = 1811.$$
$$5898{\cdot}5x + 3577366{\cdot}5\,y = 1100677.$$

The solution gives $x = -1{\cdot}6\text{s}. \pm 7{\cdot}7\text{s}.$ $y = 0{\cdot}31 \pm 0{\cdot}014\text{s}.$ The resulting speed is, $3{\cdot}226 \pm 0{\cdot}147$ miles or 5192 ± 236 meters per second.

Group III consists of reports which fail to give either the means of judging of the comparative accuracy of clocks and watches or of determining to what phase the observation refers. Many and indeed the majority of them are defective in both of these respects. Quite probably some of them are good observations but fail to give the evidence of it. So far as errors of clocks and watches are concerned the errors may be considered as belonging to the accidental class. But all errors as to the phase must be systematic. That some of them refer to more or less advanced phases is certain, and it becomes difficult to determine how many of them do so, and how great is the average tardiness. It is obvious that the effect of all such errors is to make the time too late and the resulting speed too slow. The general indications are, however, that this systematic error is not a large one. By comparing miscellaneous reports from those cities which have also given better verified reports belonging to groups I and II there seems to be a tendency of the average value of this error to fall between one-tenth and one-twentieth of the mean value of the time-interval.

In discussing this group it seems unnecessary to go to the length of formulating a hundred equations of condition, and an equally good result or even a better one may be obtained by the following more summary process. We may take them in sets, the first of which shall comprise all times within 200 miles of the centrum, the second set all between 200 and 300 miles, the third all between 300 and 400 miles, and so on until the last,

which shall comprise all beyond 800 miles. In each set we may then take the weighted arithmetic means of the times and distances as if they were single observations.

GROUP III.—*List of* 125 *miscellaneous Time Reports.*

Locality.	State.	Distance.	Time.	W't.	Remarks.
Statesburg,	S. C.	80	51m30s	1	
Columbia,	S. C.	89	52	1	
Savannah,	Ga.	89	51 53	2	mean of 3 obs.
Augusta,	Ga.	111	51 30	2	mean of 2 obs.
Laurinburg,	N. C.	135	51	1	
Darien,	Ga.	138	52 30	1	
Brunswick,	Ga.	155	52	1	
Macon,	Ga.	203	52	1	
Jacksonville,	Fla.	211	52	2	mean of 3 obs.
Fernandina,	Fla.	225	53	1	
Olustee,	Fla.	355	53	1	
Palatka.	Fla.	255	53	1	
Thomasville,	Ga.	273	52 20	1	
Wytheville,	Va.	284	52 27	1	
Knoxville,	Tenn.	302	54	1	
Zellwood,	Fla.	306	53	1	
Chattanooga,	Tenn.	329	53	1	
Norfolk,	Va.	349	54	1	
University,	Ala.	363	52	1	
Ashland.	Va.	367	52	1	
Shelby Iron Works,	Ala.	377	54	1	
Catlettsburg,	Ky.	405	52 30	1	mean of 2 obs.
Pungoteague,	Va.	410	53	1	
Decatur,	Ala.	412	53	1	
Ironton,	O.	414	55	1	
Nashville,	Tenn.	438	54 30	1	
Washington,	D. C.	452	53 41	2	mean of 4 obs.
Louisville,	Ky.	485	54 38	1	mean of 2 obs.
Baltimore,	Md.	487	53	1	
Dayton,	Ky.	487	54 11	1	
Newport.	Ky.	488	53 21	1	
Cincinnati,	O.	491	53 41	4	mean of 6 obs.
Lancaster,	O.	491	54	1	
Wyoming,	O.	501	53 41	1	
Columbus,	O.	513	53 41	2	mean of 4 obs.
Hamilton,	O.	513	54 11	1	
Paris,	Tenn.	520	56	1	
Pittsburg,	Pa.	525	54 30	1	mean of 2 obs.
Brookville,	Ind	526	53	1	
New Philadelphia,	O.	532	54	1	
Sewickly,	Pa.	535	54	1	
Mt. Vernon,	O.	536	56	1	
Wellsville,	O.	538	55	1	
Oxford,	Miss.	548	56	1	
Paducah,	Ky.	558	52 15	1	
Philadelphia,	Pa.	566	53	1	
Burlington,	N. J.	584	53	1	
Indianapolis,	Ind.	584	55	2	mean of 3 obs.
Cairo,	Ill.	588	53	1	
Titusville,	Pa.	608	56	1	
Helena,	Ark.	609	55	1	
Toledo,	O.	637	55	1	
Newark,	N. J.	640	53	1	
Jamestown,	N. Y.	642	56	1	

Locality.	State.	Distance.	Time.	W't.	Remarks.
Brooklyn.	N. Y.	643	54^{m}30^s	3	mean of 4 good obs.
New York,	N. Y.	645	54 12	6	mean of 10 obs.
Hackensack,	N. J.	654	54	1	
Warwick,	N. Y.	661	56	1	
Gowanda,	N. Y.	666	55	1	
Detroit,	Mich.	675	55 12	3	mean of 5 obs.
Valparaiso,	Ind.	705	53	1	
London,	Ont.	706	55	1	
Peoria,	Ill.	710	55	1	
New Haven,	Conn.	711	55 30	2	mean of 2 obs.
Port Huron,	Mich.	712	55	1	
Hudson,	N. Y.	747	57	1	
Hartford,	Conn.	747	54 45	2	mean of 2 good obs.
Stuyvesant,	N. Y.	760	57	1	
East Saginaw,	Mich.	766	58	1	
Albany,	N. Y.	770	56 40	1	
Fonda,	N. Y.	775	55	1	
Saratoga.	N. Y.	797	53	1	
Greenfield,	Mass.	799	55	1	
Keokuk,	Iowa.	810	56	2	2 obs.
Dighton,	Mass.	812	56	1	
Davenport,	Ia.	827	55	1	
Lake Placid.	N. Y.	827	55	1	
Jamaica Plain,	Mass.	828	57	1	
Blue Mt. Lake,	N. Y.	830	56	1	
Bellows Falls,	Vt.	832	53	1	
Boston,	Mass.	832	55 30	1	2 obs.
Dubuque,	Ia.	878	57	1	
Prairie du Chien,	Wis.	924	56 30	1	

Taking these in groups in the manner just indicated we have:

			Weight.	Residuals.
Centrum	$x + 0y =$	0	2	+ 4·06
0 to 155	$x + 111y =$	39	9	+ 1·90
203 to 284	$x + 240y =$	84	8	− ·28
302 to 377	$x + 342y =$	122	7	− 4·43
405 to 491	$x + 462y =$	158	16	− ·60
501 to 588	$x + 542y =$	184	18	− ·05
608 to 675	$x + 647y =$	217	20	+ 1·80
705 to 799	$x + 744y =$	255	15	− 4·00
810 to 924	$x + 837y =$	278	11	+ 3·85

The normal equations are:

$$106x + 55768y = 18940.$$
$$55768x + 34474772y = 11668675.$$

The solution gives $x = +4{\cdot}06 \pm 1{\cdot}7$ seconds, $y = 0{\cdot}3319 \pm 0{\cdot}0029$. The resulting speed is, $3{\cdot}013 \pm 0{\cdot}027$ miles or 4848 ± 43 metres per second. To this result some correction must be applied for the systematic error, which, as already stated, there is reason to believe probably lies between one-tenth and one-twentieth of the mean time-interval and therefore of the speed. Suppose it be taken at one-fifteenth of the amount, with a probable error of one third of the correction. This

would make the corrected result $3{\cdot}214 \pm 0{\cdot}072$ miles or 5171 ± 116 metres per second.

Stopped Clocks.

It is natural to suppose that if a clock were stopped by an earthquake and if its error at the time were known it would give the best possible record of the time of advent of the shock. An examination of the time reports of this earthquake, however, strongly contradicts this conclusion. A clock may stop at almost any phase of the disturbance. A sensitive one may pass through an earthquake of considerable violence and not stop at all. A jeweler's clock in Charleston was found going the next morning, and when the telegraph wires were re-opened its error was found to be small, showing that its escapement had missed very few beats, if any. Clocks in Columbia, Savannah, Augusta and Wilmington, N. C., in many cases kept going. Inquiry at Wilmington elicited the reply that no jewelers' clocks had been stopped. Several reports describe clocks whose rates are satisfactorily vouched for but whose times can be accounted for only upon the theory that they were stopped by the second powerful shock, which was felt at Charleston about five minutes after the principal one, *e. g.*, Branchville, S. C., Augusta, Rome, Ga., Cape Canaveral, Camden, Ala., Memphis, Tenn. There are some cities where the time of beginning is well established by independent observation and which also report stopped clocks. In every such case the time of the stopped clock is much later. Thus at Nashville the time of beginning was noted by a clock which continued going for 42 seconds and then stopped. Similar means of comparison come from Cincinnati, Covington, Ky., Pittsburg, Newark, N. J., Brooklyn and New York. And in general wherever stopped clocks can be compared with really good personal observations they invariably show a later time and usually a much later one. The difference is plainly due to the fact that it generally takes a considerable time and an accumulation of the effects of the vibrations of the building upon the pendulum to stop a clock. An attempt has been made to evaluate this difference by taking those cases where a comparison can be made between the readings of stopped clocks and independent determinations of the times of the beginning in the same locality.

Locality.	State.	Intervals by personal obs. Seconds.	Intervals by stopped clocks. Seconds.	Ratios.	Weights.
Nashville,	Tenn.	144	186	1·29	2
Covington,	Ky.	155	235	1·52	1
Cincinnati,	O.	155	195	1·26	2
Pittsburg,	Pa.	174	234	1·34	1
Brooklyn,	N. Y.	204	234	1·15	1
New York,	N. Y.	204	249	1·22	2
		Mean ratio,		1·28	

In the above table the comparison at Cincinnati takes account only of a single clock, whose error happened to be known exactly. The time of beginning in that city is also known with exceptional certainty and accuracy. It will not differ more than eight or ten seconds from 9h. 16m. (Cincinnati local mean time or 9h. 53m. 41s.). If we consider Cincinnati and suburban towns within fifteen miles of the city which are supplied with local time from the Cincinnati observatory, we have no less than twenty-two time reports, of which nine are stopped clocks. Two personal observations giving 9:15 local have been rejected because they are multiples of five. One report giving 9:17:45 has been rejected because its author, besides indicating that it refers to an advanced phase, throws doubt on his own observation. Of the remaining ten personal observations one gives 9:15:40, eight give 9:16, and one gives 9:16:30. Of the stopped clocks, three were in the central office of the Western Union Telegraph Co. They kept standard time and were read only to the nearest minute. All three are reported to have stopped at 9:54. The clock in the fire tower is the one whose error was known. Its corrected reading was 9:16:40. The remaining clocks gave (9:15), (9:16), (9:17), (9:17:20), and (9:19). Four of the latter were from the suburban town of Lockland. Reducing to standard time and taking their mean, the ratio of the time-interval by stopped clocks to that by personal observation is 1.26, a result identical with that derived from the clock in the fire tower alone and nearly the same as that in the table. There is reason to believe, however, that this ratio is a little too great for the mean of stopped clocks throughout the entire country, and especially so for those of very distant localities; for if the ratio were uniform, the absolute differences between the two kinds of data would be very wide in remote regions and small near the centrum. This is not the case. The absolute differences at very remote localities are very little, if any, greater than those at the middle distances. This difficulty prevents us from assigning any specific value to the correction and from determining its probable error. Nevertheless the comparisons just made indicate that the systematic error is probably of such magnitude that, if due allowance were made for it, the corrected result for the stopped clocks would not differ much from those of the preceding groups. While this group furnishes evidence which strongly supports the approximate correctness of the results of the other three it cannot be a source of greater precision nor can it furnish the means of reducing the final probable error.

GROUP IV.—*Stopped Clocks.*

Locality.	State.	Distance.	Time.	No. of clocks.	W't.
Centrum,	S. C.	0	51^m06^s		
Charleston,	S. C.	20	51 12	4	3
Columbia,	S. C.	89	51	2	2
Savannah,	Ga.	89	51 55	2	2
Langley,	S. C.	103	53	1	1
Augusta,	Ga.	111	52	1	1
Cochran,	Ga.	192	52	2	2
Macon,	Ga.	203	51 30	1	1
Jacksonville,	Fla.	211	52	1	1
Atlanta,	Ga.	252	52 22	4	3
Catlettsburg,	Ky.	405	53	1	1
Nashville,	Tenn.	438	54 12	1	1
Columbus,	Miss.	481	56	1	1
Covington,	Ky.	488	55	1	1
Cincinnati,	O.	491	54	3	2
Cincinnati,	O.	491	54 21	1	1
Meridian,	Miss.	500	54	1	1
Lockland,	O.	505	54 26	4	3
Havre de Grace,	Md.	515	55	1	1
Pittsburg,	Pa.	525	55	1	1
Newcastle,	Del.	538	54	1	1
Atlantic City,	N. J.	552	54	1	1
Wooster,	O.	558	55 45	1	1
Newcastle,	Pa.	565	55	1	1
Indianapolis,	Ind.	581	55	1	1
Memphis,	Tenn.	587	54 50	6	4
Cairo,	Ill.	588	53	1	1
Meadville,	Pa.	608	55	1	1
Newark,	N. J.	640	55	1	1
Brooklyn,	N. Y.	643	55	1	1
New York,	N. Y.	645	55 15	2	1
Ithaca,	N. Y.	696	55	1	1
Manistee,	Mich.	855	57	1	1

We may arrange these in groups or sets according to their distances, as was done in the discussion of group III, and obtain the following equations of condition.

		Weight.	Residuals.
0 to 89	$x + 59y = 15$	7	+ 12·29
103 to 192	$x + 150y = 69$	4	− 7·21
203 to 252	$x + 234y = 110$	5	− 16·37
405 to 491	$x + 469y = 194$	7	− 11·29
500 to 588	$x + 549y = 209$	16	+ 4·04
608 to 696	$x + 642y = 237$	5	+ 12·80
855	$x + 855y = 354$	1	− 24·97

The normal equations are:

$$45x + 183335\,y = 7172.$$
$$18335x + 9567895\,y = 3717233.$$

From which $x = +5{\cdot}0$, $y = 0{\cdot}379$. The resulting speed is $2{\cdot}638 \pm 0{\cdot}105$ miles, or 4245 ± 168 meters per second. If the correction for the systematic error has a value approximately that which has been derived from the comparisons of the stopped clocks with well determined times of particular localities, or not less than one-fifth the amount, the corrected speed would be from 5100 to 5200 meters.

We may now proceed to combine the results of the first three groups and obtain from them a single mean. The probable error of the fourth group being uncertain it is necessary to omit it. Taking the weights inversely as the squares of the probable errors we have:

		W't.
Group I,	$5205^m \pm 168^m$	2
Group II,	$5192^m \pm 236^m$	1
Group III,	$5171^m \pm 116^m$	4
Mean result,	$5184^m \pm 80^m$	

It remains to inquire whether the data indicate any variation of the speed. The answer is in the negative. The data are inconsistent with any variation of a systematic character and there is no apparent means of detecting an unsystematic one. A small irregular variation, such as might be caused by varying density and elasticity of the propagating medium, would not be inconsistent with the data; but the evidence of it cannot be separated from the errors of observation.

ART. II.—*History of the changes in the Mt. Loa Craters;* by JAMES D. DANA. Part I. KILAUEA. (With Plate I).

[Continued from vol. xxxiii, p. 433 (June), vol. xxxiv, p. 81 (August), and p. 349 (November).]

4. GENERAL SUMMARY, WITH CONCLUSIONS.

FROM the foregoing review of publications on Kilauea, it appears that we have already much real knowledge about the changes in the crater, and that this knowledge embraces facts that are fundamental to the science of volcanic action. This will be made more apparent by the Summary and Conclusions which follow. It will be convenient to consider, first, the Historical conclusions, and secondly, the Dynamical.

I. HISTORICAL.

1. *Periodicity or not in the discharges of Kilauea.*

In the sixty-three years from 1823 to 1886, there appear to have been at least eight discharges of Kilauea. Four of them were of prime magnitude—those of 1823, 1832, 1840

and 1868—distinguished by a down-plunge in the floor of the crater making in each case a lower pit several hundred feet deep. Others, as those of 1849, 1855, 1879, 1886, were minor discharges, discharges simply of the active lakes, without any appreciable or noticed sinking of the floor of the crater. The eruption of 1849 might be questioned; but it was preceded by far more activity in the crater than that of 1886. Other subterranean discharges may have occurred since 1840 of which no record exists. Even small breaks below might empty Halema'uma'u.

The mean length of interval between the first three eruptions was 8 to 9 years (xxxiv, 81). The great eruption of 1789, the only one on record before that of 1823, occurred 34 years back of 1823, or $4 \times 8\frac{1}{2}$ years; and the 1868 eruption was $3 \times 9\frac{1}{3}$ years after that of 1840.

The above approximate coincidences in interval and multiples of that interval seem to favor some law of progress. But it is not yet proved that they have any significance. The minor eruptions which have been referred to above have intervals varying from 6 to 13 years. Moreover, looking to the summit crater of Mt. Loa for its testimony, we find still greater irregularity, the successive intervals between its six great outflows from 1843 to 1887 being 9, 4, $3\frac{1}{2}$, 9, $12\frac{1}{2}$, $6\frac{1}{4}$ years.

A partial *dependence of the activity of the fires on seasons of rains* was suggested by Mr. Coan; and there is some foundation for the opinion in the times of occurrence of the Kilauea discharges mostly within the four months, March to June, as shown in the following table:

1823	March ?	1855	October.
1832	June (Jan. ?) (xxxiii, 445)	1868	April 2.
1840	May.	1879	April 21.
1849	May.	1886	March 6.

In addition, there was a brightening of the fires around the crater in October of 1863; and again in May and June of 1866; whether followed by a discharge of the Great Lake is not known. The future study of the crater should have special reference to this point.

2. *Mean rate of elevation of the floor of the crater after the great eruptions.*

After the eruption of 1823, between the spring of that year and October of 1829, an interval of $6\frac{1}{2}$ years, the bottom, if the depth was 800 feet as inferred after the measurement of the upper wall by Lieut. Malden, rose at a mean annual rate of 138 feet, or, taking the depth at 600 feet, of 93·3 feet. Lieut. Malden's 900 feet for the upper wall,

sustained, after explanation (xxxiii, 440), may need reduction on the ground that the present width of the crater is greater than in 1825, owing to falls of the walls; but it is useless with present knowledge to make any definite correction. Only general results are possible.

After the 1832 eruption, the lower pit in February of 1834, was 362 feet deep, by the barometric measurement of Mr. Douglas,* and in May of 1838, about 4½ years later it was filled to within 40 feet of the top; whence the mean annual rate of 71⅓ feet.

After the 1840 eruption, between January, 1841, and the summer of 1846, 5½ years, the 342 feet of depth, found for the lower pit by the Wilkes Expedition, was obliterated, and the floor was raised on an average 40 or 50 feet beyond this; a rise of 400 feet in the 5½ years would give for the mean annual rate, 72¾ feet.

Subsequent to 1846 the rising of the floor was slower. Between 1846 and 1868, 22 years, the rise over the central plateau is estimated at 200 feet. It is not certain that subsidences in the plateau of greater or less amount did not take place at the eruptions of 1849 and 1855, or at other times.

3. *Levels of the floor after the eruptions of* 1823, 1832, 1840, 1868 *and* 1886.

The measurements of depth already given and the mean annual rate of progress deduced are approximate data for determining the depth of the lower pit as it existed immediately after the great eruptions.

The depth after the 1823 eruption is considered above. To arrive at the depth after the 1832 eruption, the depth obtained in 1834 by Douglas has to be increased by an allowance for change during the previous year and a half, which, at the rate arrived at above, would give 450 feet. This is so much less than the estimate of Mr. Goodrich (xxxiii, 446) that it is almost certainly below rather than above the actual fact. For the depth in June 1840, the Wilkes Expedition measurement, 342 feet, should be increased for a preceding interval of seven months, which at the rate deduced above for the next four years, would make the amount about 385 feet. In 1868, according to the two estimates for the lower pit (xxxiv, 92), the depth was about 300 feet. Mr. Severance of Hilo, informed me in August last that the pit in 1868 was as deep as in 1840. The lower estimate is adopted beyond. In 1880, the lower pit of 1868 had wholly disappeared, and, according to

* See the first part of this paper. vol. xxxiii, p. 446, June, 1887, where the facts are definitely given, and also other evidence.

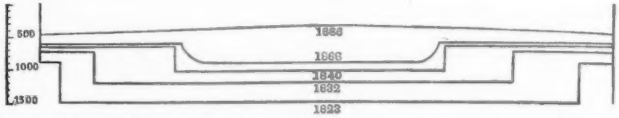
DETROIT PUBLIC LIBRARY

the description of Mr. Brigham (xxxiv, 95, from page 20 of the same volume) the bottom of the crater had already the form of a low eccentric cone, the surface rising from the foot of the encircling walls to the summit about Halema'uma'u. This has continued to be the form of the bottom, and the Government map gives the present depth. (See the accompanying Plate I).*

The following table contains (A) the above deduced figures for the depth of the lower pit; (B) the height of the *highest part* of the western wall; and (C) the level of the center of the pit below the top of the western wall.

	Depth of Lower Pit.		Height of W. Wall above ledge.	Height of W. Wall above center of bottom.	
After eruption of 1823	600	(800?)	900 (?) Malden	1500	(1700?)
1832	450	(600?)	715 Douglas	1165	(1315?)
1840	385		650 Wilkes †	1030	
1868	300		600 (550?)	900	(850?)
1886	0		500 Govt. Survey	380	

These numbers have much instruction in them notwithstanding all uncertainties. The following diagram, based on them, represents a transverse section of the crater at the several levels of the floor and black ledge. The minimum depths for 1823 and 1832 are here accepted, there being in them no probability of exaggeration.



The sides of the pit in this section are made vertical from 1823 onward—an error which there are no data for correcting.

* Mr. Brigham's paper gives results of his barometric measurements in 1880, that are not reconcilable with those of the Government or of earlier determinations except on the assumption of great changes of level between 1880 and 1886 and small difference of level as regards the base of the cone between 1840 and 1880. His depths are 650 feet at the northern base of the cone near the place of descent, where Wilkes made the depth 650 feet, and the Government map in 1886, 481 feet; and 300 at Halema'uma'u, where the Government survey made the depth nowhere less than 320 feet. By the reported measurements, the cone had a height of 350 feet in 1880, and of 150 in 1886; accordingly the base of the cone to the north had been raised 140 feet in the 6 years after 1880 while nothing or little in the 40 years preceding it, although large overflows during the interval, adding 50 to 100 feet to its height, are mentioned by Mr. Brigham and others; and the level about Halema'uma'u had lost 30 feet between 1880 and 1886. The latter difference of level is not impossible; but the former it is natural to question, since so great a rise of the border in 6 years could not have taken place by any method without being noticed.

† The Wilkes Expedition appears to have made the place of encampment the datum point. The exact position of the place is not precisely known. It may probably be ascertained nearly enough to give by leveling the height with reference to the Volcano House; but at this time the height has not been determined.

The diminution since 1823 in the height of the western wall above the black ledge is probably due almost wholly to the *flooding* of the black ledge. According to the numbers, this diminution was about 185 feet from 1823 to 1832; 65 from 1832 to 1840; and 160 feet since 1840. But subsequent to 1840, as Emerson's map shows, the diminution of level along the black ledge or lateral portion of the pit has been much less than over the central, the amount of diminution at center having been at least 200 feet, and about Halema'uma'u 250 to 300 feet.

The bottom of the emptied basin of Halema'uma'u after the eruption of 1886 was 900 feet below the Volcano House; and this was 50 to 100 feet above the liquid lava of the basin in 1840.

The relations between the amounts discharged in 1823, 1832, 1840 and 1868 could be approximately inferred from the size of the lower pit as determined by the mean breadth of the black ledge, if the width of the crater were the same at all periods. But in addition to other uncertainties we have that arising from sloping walls, and very sloping on the southeast side. The pit of 1823 should therefore have been narrower at the black-ledge level than that of 1840. Still, the width of the ledge in 1823, according to all the observations and maps, was so very narrow compared with that in 1840, that we may feel sure of the far larger amount of the earlier discharge. But the depth of the lower pit was also greater in 1823, and this requires an addition of one half to the amount which the area of the lower pit suggests, if not a doubling of it.

For an estimation of the discharge of 1832 we are still more uncertain as to the mean width of the ledge. But that the ledge was narrow, much like that of 1823, is most probable. In 1868 the down-plunge, according to the most reliable estimate, was a fourth less than in 1840, the depth of the pit being not over 300 feet.

There are no sufficient data for putting in figures the relative amounts of discharge at the great eruptions. But the general fact of a large diminution in the amounts since the first in 1823 is beyond question. It has to be admitted, however, that we can hardly estimate safely the discharge in 1868 from the size of the pit then made, since the thickness of the solid floor of the crater may have prevented as large a collapse in proportion to the discharge. But it did not take place until 28 years had passed after 1840, and this strengthens the evidence as to an apparent decline in the outflows, whatever be true as to the activity. The following eighteen years produced only minor eruptions.

4. *Other points in the Topographic history of the Kilauea region.*

Besides the points considered, the chief events in the topographic history since 1823 are: (1) avalanches and subsidences

along the border of the crater; and (2) overflowings and changes of level over the bottom.

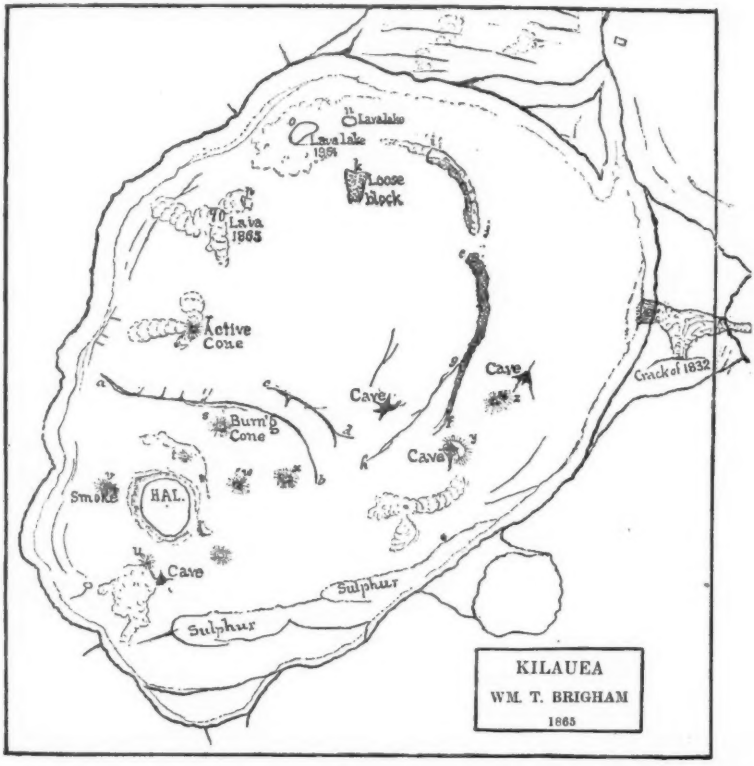
Down-falls of the walls and sinkings of the borders are reported as having been common during periods of eruption and earthquake; but direct testimony as to the amount at any time does not exist. In view of the great numbers of deep fissures about Kilauea (xxxiv, 358) and the many fault-planes and sunken areas, the fact cannot be doubted; and Mr. Brigham has estimated* that the crater in 1880 was five per cent larger than it was 18 years before. The increase in mean diameter on this estimate would be 300 feet. I think the estimate large.

Of the gradual changes over the bottom of the crater pretty full records have been gathered from the published accounts. But we naturally look with the greatest confidence to the maps that give the results of personal surveys, especially with regard to changes in the outline of the walls. We have two such maps—that made personally by Wilkes in 1841, and that by Brigham in 1865, besides the recent map by the Hawaiian

* This Journal, III, xxxiv, 20.

government, under Professor Alexander's charge, completed in 1886. For convenient comparison the reduced copies of Wilkes's and Brigham's maps are here reprinted; that of the Government survey is reproduced in Plate 1 of this volume.

In using the maps a difficulty is encountered at the outset in consequence of a discrepancy between the first two of the maps and that of the Government survey as to the dimensions of the crater. Accepting the latter as right, the scale of each of the others should be diminished about an eighth to bring the three



maps into correspondence. The maximum diameters in Wilkes's map, using his own scale, are 16,000 and 11,000 feet; while according to the Government map they are about 14,000 and 9800 feet; and the length of the line from K to B on the former is 10,000 feet and on the latter 8500 feet. It is certain that the crater in 1840 was not *larger* at top than now. Mr. Brigham's map appears to have been carefully made, but for

some reason it requires the same correction. Such a discrepancy unavoidably throws doubts over other parts of the maps. But while closer study increases confidence in Mr. Brigham's, the result is not so satisfactory with the Wilkes map. The following remarks suppose the scale of the two maps to have been corrected.

Wilkes's map of Kilauea.—The relations of the map made by Capt. Wilkes to that of the Government Survey is exhibited on Plate 1, the outline of the crater from the former being drawn over the latter where it is essentially divergent. This diverging part of the outline is lettered A B C D E, D E showing the outline of the sulphur banks of 1840. Besides this, the outline of the black ledge of 1840 is indicated by the line L L L, and its surface by cross-lining. Some important features from Brigham's map also are drawn in and indicated by italic letters. These include small lava-lakes, the outline of Hale-ma'uma'u as given by him, small cones, fissures, etc.

The plate shows, in the first place, a general conformity between the eastern wall of the Wilkes and Government maps, but a far greater width of sulphur banks in that of 1840. These sulphur banks have become submerged by the lava flows of later time, and thus the floor of the crater has in this part been extended eastward about 2500 feet. Of this I believe there is no doubt.

In the second place, there is no conformity between the maps in the southern half of the western wall. Instead, on Wilkes's map, south of the Uwekahuna station, the west wall (A B C on Plate 1) is 1200 to 1500 feet inside of the position of the existing wall as given on the Government map; showing, apparently, a very great topographical change on that side of Kilauea since January, 1841, and one of the highest interest; a change either by subsidence, or by overflowings of lava streams, adding nearly 10,000,000 square feet to the area of the crater.

Looking about for other evidence of this change, and finding no allusion to it in Mr. Coan's reports, and nothing in Mr. Lyman's paper or map of 1846 (xxxiv, 83), but, on the contrary, a general conformity in Lyman's map to that of the recent survey, I was led to question the unavoidable conclusion, although it involved a doubt of the Wilkes map. A consequence of the doubt was my sudden determination to revisit Hawaii and sustain the conclusions from Wilkes's map if possible; for they made too large a piece in the history to be left in doubt. Mr. Drayton's sketch, reproduced as Plate 12 in a former part of this paper (xxxiii, 437), suggested the method of deciding the question.

The conclusion arrived at while on the ground in August last, was that Drayton's sketch represented sufficiently well the *existing* outline of that part of the crater, that is, of the crater of to-day. It follows, consequently, that the west wall of 1841 and of 1887 are essentially alike in position, and that Wilkes's map of the southern half of its western wall is 1200 to 1500 feet out of the way.

To make this large correction on Wilkes's map involves some other large changes; namely, the widening greatly of the black ledge west of Halema'uma'u; and also a probable widening of the Halema'uma'u part of the lower pit with the entrance-way to it. Both changes are favored or required by Drayton's sketch. The entrance-way referred to is thus widened (on the ground of Drayton's sketch chiefly), from Wilkes's 800 feet at top of wall to about 1500 feet. The dotted line L′L′L′ on Plate 1 is believed to show the probable limit of the 1840 black ledge along the west border of Halema'uma'u.*

So large an error in so small a map excites an uncomfortable query as to all the rest of its details; fortunately not, however, as to the depth of the crater and its lower pit, since this was obtained by the independent measurements of two of the Expedition officers, Lieutenants Budd and Eld. Moreover the map may be used for some general conclusions.

Drayton's sketch was probably taken from the point marked *Dn* on the map, south of Wilkes's encampment, or on the higher land to the west of this point.†

The sketch has three headlands along the west wall. Of these, only the second and third exist as they then were. The first or nearest stood, as the sketch shows, between the Uwekahuna summit and the second of the deep western bays on Wilkes's map of the lower pit, a spot where great subsidence has taken place in the western wall, east or southeast of the Uwekahuna station (xxxiv, 358); and the sketch appears to be sufficient testimony for the reality of this subsidence and its amount.

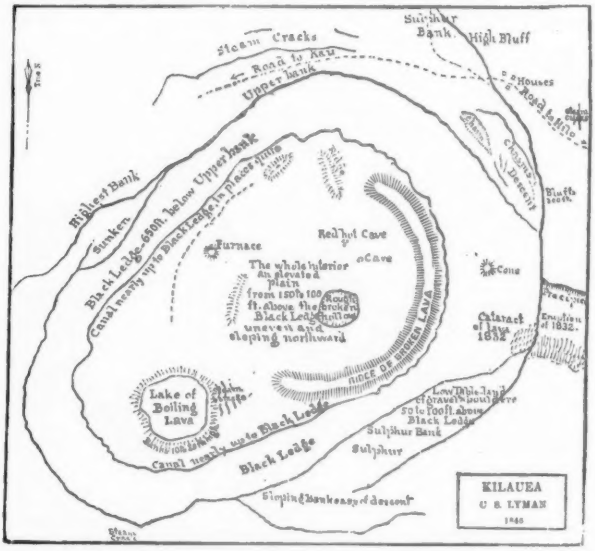
Looking again at Wilkes's map (page 20), it is seen that, as already stated, the outer *eastern* wall has the same position that it has on the Government map, but that the *southeastern* wall of Wilkes is not continuous with his western, but is an independent one situated more to the eastward; and here came in the error. The error is so extraordinarily great that we sought while at the crater for some extraordinary excuse for it. We concluded (Mr.

* Another smaller change is proposed in the eastern outline of the lower pit, near *e*, suggested by Brigham's map. No attempt is made to give on the Government map Wilkes's outline of the southeast angle of the crater, as the existing features offer no available suggestions.

† While the sketch bears evidence of being generally faithful to the facts, the foreground appears to be modified for the artistic purpose of giving distance to the rest.

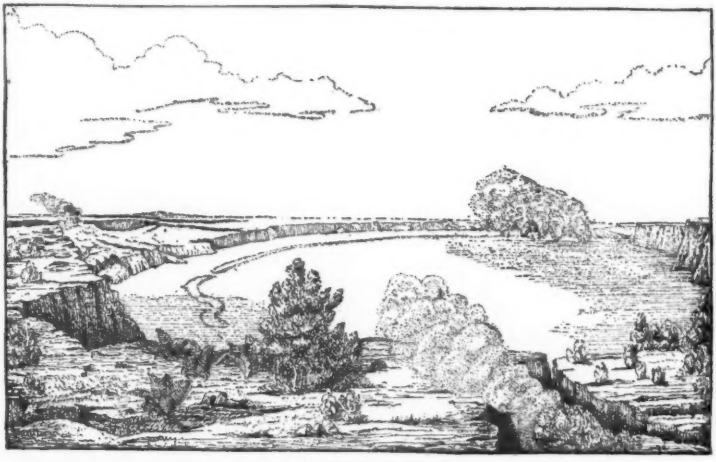
Merritt and myself) that Captain Wilkes in his visit to "all the stations around the crater in their turn" (xxxiii, 451), on reaching the high Uwekahuna summit, instead of relying on his angles, probably took the shorter way of sketching in the ridges that stood to the southeast and south; and that he was led by insufficient topographical judgment to throw the wall, together with the parallel ridge outside of it, too far to the eastward. The error, as we saw when there, is an easy one for him to have made. This cramped the map to the southward about the Great South Lakes, but the angles taken from other stations were not enough to serve for the needed correction and the sketching was allowed to control the lines. However this may be, it is lamentable that a correct map, with a careful determination of heights around the crater, was not made in 1840.

An important error also exists in Wilkes's determination of the longitude of his encampment near the crater. The Surveyor-General of the Islands, Prof. Alexander, informed me that the position Wilkes gives Kilauea is 8½ minutes too far west; and that the error affects all the southeastern quarter of his map of Hawaii including the position of the coast line. His longitude of the summit of Mt. Loa is correct.



Mr. Brigham's map.—Mr. Brigham's map is a register of the facts of 1864–65, a period just half way between 1841 and 1887. It indicates unfinished changes in progress within the crater which were commenced in 1840, and other conditions that became pronounced only in later years.

The remnants it represents of Lyman's ridge of lava-blocks, —the talus of the lower wall uplifted upon the rising floor of the lower pit—has already been referred to (xxxiv, 89). That it may be fully appreciated, the reader is directed again to Mr. Lyman's map, here reprinted with corrections by him;* and then to Plate 1, which shows these remaining parts of the long ridge drawn, from Brigham's map, on the recent map of the Government survey (lettered *ef*, *gh*). The ridges are not put as far from the east wall of the crater as on Brigham's map, but are made to accord with the statement of each Lyman and Coan, and of Brigham also, that they followed the course of the lower-pit wall of 1840 a little inside of its position, over the site of the original talus—Wilkes's position of the wall being adopted except for a short distance near *e*. Halema'uma'u, as



the dotted line inside of the basin of the Government map shows, was small in 1864–65, it being only 1,000 feet in diameter and but little raised above the level of the liquid lavas.

The preceding additional view of the crater is introduced at this place because it contains the remains of the Lyman ridge as mapped by Mr. Brigham, and is further testimony as to its

* The copy of Prof. Lyman's map, reproduced on page 85 of the last volume of this Journal, is not from a tracing of his original map, but from a roughly drawn copy left on the islands. The original was lost by him, as he informs me, when in California on his return to New Haven. He has here placed the "canal" along side of the ridge, in accordance with the statement in his description and also in his note-book of 1846, which makes the interval between them "10 to 40 and 50 yards." Before publishing the map I endeavored to obtain corrections from him. But on account of his illness at the time I could not communicate with him.

position with reference to the walls. The view is from a photograph of a painting made by Mr. Perry, a California artist, in 1864 (?) the year of Mr. Brigham's first visit, and which I received from Mr. Brigham in March, 1865.* The sketch of the crater bears evidence throughout of great accuracy of detail. It has much interest also because it gives, with clear definition, the outlines of the depression (on the left) between Kilauea and the side crater Kilauea-iki;—in which respect it is more satisfactory than Drayton's sketch. The point of view was on the north border of Kilauea, a little to the east of Drayton's; and consequently it necessarily differs widely from Drayton's sketch as regards the headlands of the western wall, yet resembles it quite closely on the eastern side. Halema'uma'u is not defined; and this is explained by Mr. Brigham's map and description.

Mr. Brigham's map shows also the positions of active lava-lakes in 1864 or 1865, lettered *i*, *k*, *l*, *m;* and the interesting fact is to be noted that two of them, to the northwest, *i*, *k* lie *at the edge of the black ledge*, while *l*, *m* are a little back of it, but in a line with *i*, *k*.

The long curving line of deep fissures and fault-plane, already referred to as marking the outline of the Halema'uma'u region, is seen on Plate 1, at *a b*, not to be concentric with the Halema'uma'u basin of either Brigham's map (p. 21) or of the recent map; but to that of Halema'uma'u *plus* the New Lake region of 1884 to 1887. Thus in 1865, when Halema'uma'u appeared as a small basin 1,000 feet broad (not half its existing breadth), the fissure indicated the presence of deep-seated conditions as to the fires and forces, that finally ultimated in its extension over the New Lake area. And the expression of this fact in 1865 was doubled by a second concentric fissure 500 feet farther north (Plate 1, *c d*). Further, four of the cones mapped by Brigham in the vicinity of Halema'uma'u in 1865, *p*, *q*, *r*, *s*, on Plate 1, are inside of the existing Halema'uma'u basin; and one of the others, *o*, is near the north border, and another, *t*, is close by the east side of New Lake.

On Mr. Brigham's map, the position is given of a very large loose block of lava, which is shown at *w*, on Plate 1. It lies, as is seen, in the northwest part of the crater, and is over the lower edge of what in 1840 (see Wilkes's map, p. 20) was an inclined but even lava plain to the bottom that had been made in 1840 by an oblique down plunge (xxxiv, 82) carrying the inner side of the great mass down and leaving the other, that against the black ledge, on a level with the ledge, with a broad

* See Brigham's Memoir, page 419, where a wood-cut from it is introduced, but without doing the photograph justice. Mr. Brigham does not state in his memoir the date of the painting. "Perry" is mentioned as the painter on page 468.

fissure between. The block probably slid down the slope to its bottom; and, as the talus at the bottom of the lower wall was lifted on the rising floor to make Lyman's ridge, so it appears that this loose block was lifted in the northwest corner; and the lift along that part of the crater consisted in the restoring of the half engulfed mass with the lava-block on its surface, to its former horizontal position—the position it had when Mr. Brigham's map and observations were made.

It is interesting to note thus how the 1864–1865 condition of Kilauea grew out of that of 1840, and foreshadowed that of 1887. It is worthy of consideration also that just as the fault-plane *ab* is concentric with the Halema'uma'u basin *plus* New Lake, so the far greater Kilauea fault-planes, 2000 to 5000 feet north and northeast of the crater (xxxiv, 358), are concentric, not with Kilauea, but with Kilauea *plus* Kilauea-iki.

2. DYNAMICAL CONCLUSIONS.

General cycle of movement in Kilauea.—The history of Kilauea, through all its course since 1823, illustrates the fact that the cycle of movement of the volcano is simply: (1) a rising in level of the liquid lavas and of the bottom of the crater; (2) a discharge of the accumulated lavas down to some level in the conduit determined by the outbreak; (3) a down-plunge of more or less of the floor of the region undermined by the discharge. Then follows another cycle: a rising again, commencing at the level of the lavas left in the conduit by the discharge; which rising continues until the augmenting forces, from one source or another, are sufficient for another outbreak.

In 1832 the conditions were ready for a discharge when the lavas had risen until they were within 700 or 800 feet of the top; in 1840, when within 650 feet; in 1868, when within 500 or 600; in 1886, when within 350 feet. The greater height of recent time may seem to show that the mountain has become stronger, or better able to resist the augmenting forces. But it also may show a less amount of force at work. In 1823, 1832 and 1840, the down-plunge affected a large part of the whole floor of the crater, which proves not only the vastness of the discharges, but also indicates active lava through as large a part of the whole area preceding the discharge, while in 1886, the down-plunge and the active fires in view were confined to Halema'uma'u and its vicinity. It was not in earlier time, therefore, the greater weakness of the mountain, but probably the greater power of the volcanic forces.

The broad low-angled cone which the volcano tends to make, has a great breadth of stratified lavas to withstand rupturing forces. How great may easily be calculated by comparing a

cone of 8° or 10° with one of 30°, the latter the average angle of the greater volcanic mountains of western America; and this suggests important differences in the results of volcanic action independent of those consequent on the possible prevalence of cinder-ejections in the latter. But somehow or other Mauna Loa breaks easily—very easily, its quiet methods say—and it seems to be because such rocks, however thick, can offer but feeble resistance to rupturing volcanic agencies.

In the discussion beyond of the operations going on and of their causes, I speak, I, of Kilauea as a Basalt-volcano, the basis of its peculiarities; II, of the size of the Kilauea conduit; III, of the ordinary work of the volcano; IV, of its eruptions; and V, of the contrast in volcanic action between Kilauea and volcanos of the Vesuvian type.

I. KILAUEA A BASALT-VOLCANO.

1. *The mobility of the lavas.*—The phenomena of Kilauea are largely due to the fact that it is a basalt-volcano in its normal state. By this I mean, first, that the rock-material is doleryte or basalt, and secondly, that the heat is sufficient for the perfect mobility of the lavas, and therefore for the fullest and freest action of such a volcano. It is essentially perfect mobility although there is not the fusion of all of its minor ingredients, that is of its chrysolite and magnetite. This is manifested by the lavas, whether they are in ebullition over the Great Lake, throwing up jets 20 to 30 feet high, throughout an area of a million square feet or more, or when only splashing about the liquid rock and dashing up spray of little lava drops from areas of a few square yards. There is in both conditions the same free movement, almost like that of water, and suggesting to the observer no thought of viscidity. Of the two conditions just mentioned, the former was that of November, 1840, the latter that of August, 1887; and that of August seemed to be the more wonderful, because we naturally look for some of the stiffening of incipient solidification where only a few square yards of lava are in sight.

2. *This mobility is dependent largely on the fusibility of the chief constituent minerals of the lava.*—Along with augite, a relatively fusible species, the rock contains, as its other chief constituent, labradorite, almost as fusible as augite, and the most fusible of the feldspars. Andesine and oligoclase are less fusible feldspars, and orthoclase is of difficult fusibility. Thus in this prominent physical character the feldspars widely differ, and accordingly there should be, and are, volcanoes of different characteristics, for example, Andesyte volcanoes, in which oligoclase or andesine is the pre-

dominant feldspar, and Trachyte and Rhyolyte volcanoes in which orthoclase is a chief constituent; and, besides these, there are also intermediate grades or kinds.

The differences in form and action among these kinds of volcanoes depend chiefly on the physical quality of *fusibility*, but partly on that of *specific gravity*.

Neither of these qualities, it is to be noted, has any relation to the *acidic* or *basic* character of the feldspar or rock, that is to the amount of silica present. The distinction of *basic* and *acidic*, of great interest mineralogically and chemically, has in fact little importance in the science of volcanoes, while that of fusibility is fundamental. The most basic of all the feldspars, anorthite, is as little fusible as the most "acidic" of feldspars, orthoclase, and more so than the equally "acidic" albite.* It is plain therefore that the quality of being *basic*, does not explain the fusibility of the lavas. Neither does it explain any other of the physical characteristics on which the peculiarities of the volcano depend.

It is also true that the chrysolite (or olivine), the ultra-basic constituent of the lavas, has little influence on their physical characters except through its high specific gravity—which is about 3·3 to 3·4. The mineral chrysolite is infusible, and cannot *increase* the mobility of the lavas; and there is commonly not enough of it in the Kilauea rocks to diminish the mobility; for a large part of the lava contains less than 5 per cent, and much of it less than ·1 per cent. Chrysolite, is *ultra-basic;* but this quality has little volcanic importance. It is not the little amount of silica in it that is influential volcanically but the much iron, the ingredient that gives it its high density or specific gravity. The presence of much chrysolite may affect the distribution of the lavas in the conduit, or of the out-flows from the conduit, on account of their high density; but it does not accomplish this through the ultra-basicity of chrysolite, but through its ultra-ferriferous character, and the conditions under which it is formed.

3. *The degree of mobility is dependent also on temperature.* —It is probable, that at the temperature of fusion, or better a little above it, all the feldspars, the least and the most fusible, are nearly alike in mobility. But the lower the degree of fusibility the less likely is the heat to be deficient, or below that required for complete fusion and mobility; and here comes in the great difference among them as regards lavas and volcanoes.

The basalt-volcano has special advantage over all others in this respect, as the copious Mount Loa lava-streams and the

* In my Manual of Mineralogy and Petrography, page 436, I point out further that the distinction of alkali-bearing and not alkali-bearing among the silicates is of much more geological importance than the much used one of acidic and basic.

immense basaltic outflows of other regions exemplify. In Hawaii the heat required for the existing mobility is no greater than the deep-seated conditions below the mountain can keep supplied, in spite of cooling agencies from the cold rocks, the subterranean waters and the air; it is no greater than it can continue to supply for half a century and more, as the records have shown; and supply freely to the top of a conduit 3000 to 3500 feet above the sea-level, and even to the top of another conduit but twenty miles off, rising to a height of 13,000 feet above the sea-level. The temperature needed for this mobility judging from published facts, is between 2000° F. and 2500° F. The fusing temperature of augite and labradorite has not yet been determined. We are certain that a white heat exists in the lava within a few inches of the surface; for the play of jets in a lava-lake makes a dazzling network of white lightning-like lines over the surface; and white heat is equivalent to about 2400° F. Considering the height of Mt. Loa and the greatness of its eruptions, and the vastness of basaltic outflows over the globe, we may reasonably assume that the temperature needed for the normal basalt-volcano has long been, and is now, easy of supply by the earth for almost any volcanic region; and that the difficulty the earth has in supplying the higher heat for equal mobility in a trachyte or rhyolyte volcano is the occasion of the common semi-lapidified pasty condition of their outflowing lavas.

Even if the higher temperature required for orthoclase-lavas, were always present quite to the surface in the volcano, the ordinary cooling influences of cold rocks and subterranean waters and air would be sure to bring out, in some degree, on a globe with existing climatal conditions, the characteristics of the several kinds of volcanoes designated.

I do not say that this higher heat required for the complete fusion of trachyte or rhyolyte is wanting at convenient depths below; for it has been manifested in the outpouring of vast floods of these rocks through opened fissures, many examples of which over the Great Basin are mentioned in King's "Systematic Geology" of the 40th Parallel. But in the volcano, whose work, after an initial outflow, is carried forward by periodical ejections and requires for long periods a continued supply of great heat, the more or less granulated or pasty condition of the outflowing orthoclase-bearing lava streams is the usual one. Consequently, when a volcano changes its lavas from the less fusible to the more fusible, as sometimes has happened, some change in the features of the volcano should be looked for, except perhaps when the change occurs directly after the initial discharge.

Here the question suggests itself whether the temperature existing at depths below may not be one of the conditions that determine whether the discharged lavas shall be of the less fusible or the more fusible kind.

But a *basalt*-volcano also may fail to have heat enough for perfect fusion, and hence have partially lapidified or pasty lavas, and thus be made to exhibit some of the characteristics of the other kinds of volcanoes. This condition may result from three causes: (1) A decline in the supply of heat of the conduit, as when the partial or complete extinction of the volcano is approaching; (2) When the lava is discharged by lateral openings or fissures, in which case the lateral duct of lava may not be large enough to resist completely the cooling agencies about it; (3) The sudden entrance of a large body of water into the conduit.

The effects from the *first* of these conditions—declining heat connected with approaching extinction—are strikingly exemplified in two great volcanic mountains of the Hawaiian Islands, Mt. Kea on Hawaii, and Haleakala on Maui. Those of the *second*, in which the ejections are from lateral openings, are abundantly illustrated in the cinder and tufa cones of the islands, and also in widespread cinder or ash deposits through the drifting of the ejected material by the winds. The *third*, a sudden incursion of waters through an opened fissure, if a possibility, should both lower the temperature and produce violent projectile results, and even Kilauea bears evidence of at least one eruption of great magnitude which was thus catastrophically produced; for the region bordering the crater on all its sides, and to a distance of ten or fifteen miles to the southwest, is covered with the ejected stones or bowlders, scoria and ashes of such an eruption.

4. *Eruptive characteristics of a Basalt-volcano.*—The obvious results of superior mobility and density in lavas, are, as in other liquids:

(1) First: greater velocity on like slopes, and thus an easier flow, with less liability to be impeded by obstructions; a lower minimum angle of flow, and consequently a less angle of slope for the lava cones.

(2) Secondly: The vapors ascending through the liquid lava encounter comparatively feeble resistance, and hence the expansive force required for escape of bubbles through the lava to the surface is feeble; and so also are the projectile effects due to the explosion of the bubbles. Hence the projected masses commonly go to a small height—it may be but a few yards—and fall back before cooling, instead of reaching to a height that involves their cooling and solidification in the fall and the making thus of cooled fragments of lava or scoria, called cinders and volcanic ashes.

The projectile process in the basalt-volcano, as long as it is in its normal stage, makes not cinder-cones, but *dribblet-cones*, 15 to 40 feet high, out of the projected masses, the falling driblets becoming plastered together about the smaller places of ejection. Such cones consist of cohering drops, clots, pancake-like patches, or abortive streamlets, and form into spires and columns on rude bases and take other fantastic shapes. They are necessarily small, and mostly of blow-hole origin, because when the vent is broad, like a lava-lake, the jettings fall back into it again; yet enough may fall on the margin of a lava-lake to gradually raise and steepen its border. Such driblet-cones are of all angles from 30° to 90°. Among the projectile results of volcanoes, driblet-cones are at one extremity of a series, and cinder or tufa cones, many hundreds of feet high, at the other. A cinder cone of 1000 feet in height has 15,000 to 20,000 times the bulk of any driblet-cone. The process is one; but the result varies with the mobility and fusibility of the lavas.

Further: in the great lava cone of a basalt-volcano in its normal stage, cinder or tufa deposits rarely alternate with the large lava-streams, while they commonly alternate in other kinds of volcanoes.

Further: cinder cones and beds of volcanic ashes may form about a basalt-vocano, as already explained, whenever the condition of insufficient heat is in any way occasioned.

The above views as to the characteristics of a normal basalt-volcano are sustained by the facts from the volcanic mountains of all the Hawaiian Islands.

In the first place, the slopes are not only the lowest possible, usually from 1° to 10°, but continuous flows of 10° to 90° occur. I have seen many of them descending as unbroken streams vertical precipices on southern and western Hawaii.

Again the alternation of the lava-streams of the great volcanoes with deposits of volcanic sand, scoria or stones that were ejected from the great craters, is of rare occurrence, and such deposits make only thin beds of the kind whenever they occur. In such examinations as I have been able to make of the walls of Kilauea and Haleakala, and of the precipices and bluffs of Oahu, I have not succeeded in finding cinder or tufa deposits among the layers. The walls of Kilauea are stratified from top to bottom, but with lava-streams, and comparatively thin streams; I could find no evidence, in my examination of its walls, of any intervening stratum or bed of scoria, tufa or stones like that which now covers its border. This testimony is not conclusive as to the absence of such projectile eruptions in former times, for thin beds of scoria or sand like that just referred to—its thickness is only 25 to 30 feet—might be fused

and annexed to the succeeding lava-flow. But the evidence against *great* tufa deposits, excepting those from lateral ejections, is, I believe, sufficient; and by great I mean 50 or 100 feet; not the 1000 feet and more common in the regions of the Rocky Mountains and the Pacific border.

On the island of Maui, I found no such beds of projectile origin in the walls of Haleakala, or in those of Wailuku valley the probable crater cavity of western Maui. On Oahu, the pitch of the layers of lava along the Manoa and Nuuanu valleys is only 1° to 3°; and in the precipices and bluffs which bound them I saw no layer of tufa. The thick tufa deposits are confined to cinder and tufa cones, and these are common.*

This point needs investigation; for the existence of even thin tufa beds in alternation with the lava beds of the great volcanoes of the islands, may still be true, and such facts would have much interest.

5. *The crater of a basalt-volcano is the same in origin, history and functions as those of volcanoes of other kinds, but differs usually in form.*—The crater of a great volcano probably has always its beginning—as I set forth in my Exploring Expedition report—in a great discharging fissure. But once open, it usually continues open until a temporary or final decline of volcanic action, whatever the kind of volcano. It continues open because (1) of the fixed position of the supply conduit; because *secondly* of the conduit-work going on through it in the discharge of vapors and lavas; and because, *thirdly*, of the down-plunges in the crater consequent on the undermining which the discharge of the conduit occasions. The open end of a deep-reaching conduct determines thus, by its discharges and the subsequent underminings, the existence of the crater; and the crater, by the work done within and about it, makes the volcanic cone. This appears to be the order of rank or importance in the phenomena—the crater begins in the opened fissure and is the indicator and future builder of the cone. In the history of the volcano, the era of summit outflows may pass, and only lateral discharges take place; and still the discharge of vapors from the lava conduit and the accompanying movements in the lavas, together with the down-plunges in the crater following the discharges, will keep the crater, or portions of it, in continued existence, and the work of eruption or outflow, if subaerial, is still adding to and shaping the cone.

This is the present stage of Kilauea and Mt. Loa; and these are the results as they exemplify them. The action, functions

* The cinder or tufa deposits of lateral cones have often great extent. This is well seen on Oahu where Diamond Hill, Punchbowl, and the region about Aliapaakai or the Salt Lake, are examples.

and processes are the same whether the lavas fill up to the summit before outflowing, or become discharged at a lower level by an opened fissure.

Examples in the Hawaiian Islands teach also that volcanoes may end with an open crater over 2,000 feet deep, like Haleakala, a cone 10,000 feet high, or with a filled crater, as in the case of Mt. Kea, 13,800 feet high.

The preceding remarks about the permanence of craters apply to other kinds of volcanoes as well as the basaltic; but in the form of the crater the basalt volcano has peculiarities, owing to the mobility of the lavas and the paucity of cinder discharges. The ordinary crater of such volcanoes is pit-like, with the walls often nearly vertical, and the floor may be a great, nearly level plain of solid lavas. The liquid material of the extremity of a conduit works outward from the hotter center, through the fusing heat and the boiling and other cauldron-like movements; and hence, where the mobility favors freedom of action in these respects, it tends to give the basin or crater a nearly circular form with steep sides—an explanation I give in my Expedition report. Besides, when the discharge takes place there is usually a fall of the walls which is still another reason for vertical sides, and the pit-like form.

The small lava-lakes of Kilauea, and the Great South Lake also after a discharge, (or an eruption as it is usually called) are literally pit-craters. Such was the condition of the Great Lake after the eruption of 1886. They all illustrate how the great pit-crater, Kilauea, was made. The lower pits of 1823, 1833, 1840 are other examples.

Such pit-craters are normally circular; but where there is a large fissure beneath the crater, they may be much elongated.

From the considerations which have been presented we see why the volcanic mountains of the Hawaiian Islands, with slopes rarely exceeding 10° in angle, differ so widely from the great andesyte cones of western North America, with their high slopes of 28 to 35 degrees. We see that the fact of being basalt-made means much in a volcano; that it affects profoundly all the movements and the results of those movements as well as the shapes of the mountains and of their craters.

[To be continued.]

Art. III.—*The Analysis and Composition of Tourmaline;* by R. B. Riggs.*

Apart from the work by Rammelsberg (Pogg., lxxx, 449, lxxxi, 1, cxxxix, 379, 547), very little has been done toward solving the question of the composition and constitution of the varieties of tourmaline. Their apparent complexity and the difficulties attending the determination of certain constituents have possibly turned many aside, possibly also the impression that with Rammelsberg's investigations the matter was settled. While Rammelsberg's work was comprehensive and was good for the times, his analyses are so seriously faulty in certain important respects, as to justify a new investigation. Though the direct estimation of both water and boric acid would seem to be of the highest importance, before any satisfactory conclusions could be reached with reference to the constitution of tourmaline, we find that, having failed in one single attempt to determine the water directly, he falls back on the loss on ignition, deducts therefrom an amount equal to the amount of silicon tetrafluoride, representing the fluorine found in the mineral, and calls the balance water. He takes it for granted that the fluorine is driven off quantitatively. But while this supposition is questionable, it is not the ground of objection. In the revision (Pogg., cxxxix, 379) of his earlier work, Rammelsberg comes to the conclusion that the iron contained in tourmaline is all there in the ferrous condition, yet wholly ignores the fact of its possible oxidation on ignition, especially an ignition such as would be necessary to expel the fluorine. In a few cases boric acid is determined directly, but by a method (Stromeyer's) which has ever been counted one of the most unsatisfactory. In the majority of the analyses it is estimated by difference. But if the results called water are incorrect and low, as they surely are, the boric acids ought to be correspondingly high or the analysis must be elsewhere at fault.

The direct estimation of water being possible, and a satisfactory method for determining boric acid having lately been devised by Dr. F. A. Gooch, (Am. Chem. Jour., Feb., 1887), new tourmaline analyses seemed desirable. Through the kindness of many, abundant and varied material has been at my disposal.

* An abstract of a paper which is to appear in a forthcoming Bulletin of the U. S. Geol. Survey.

Methods of Analysis.

A few words on the methods of analysis may not be out of place here, that the character of the work may be the better judged.

Water.—The water was directly determined by igniting a mixture of the mineral and carbonate of soda in a Gooch tubulated crucible, the sodium carbonate being used to hold back any fluorine that might otherwise be driven off. The carbonate of soda used was first fused, and then, in order to ensure perfect dryness, the mixture of mineral and reagent was again dried in an air bath at 105° C. for two or three hours. This estimation, as well as all the other more important ones, was made in duplicate.

Boric acid.—Where the tourmaline contained fluorine, the same portion was used for determining both the boric acid and the fluorine, the filtrate, from the mixed carbonate and fluoride precipitates, being used for the estimation of the boric acid. The borate of lime, which may be formed, is sufficiently soluble in hot water so that no difficulty is experienced in bringing it quantitatively into the filtrate. After evaporating this filtrate to a conveniently small volume, it is brought into a retort and acidified with nitric acid. The boric acid is then volatilized as methyl borate, according to the Gooch method, and weighed as borate of lime. It is scarcely necessary to say that throughout this treatment, nitric acid should be used as the neutralizing reagent, and that, if care be taken in its use, in no case need the amount of salt, which is to be brought into the retort, become inconveniently great. Where no fluorine is present, the soda fusion may be digested with water at once, the solution, containing the borate of soda, filtered off, neutralized and treated as above indicated. One might save himself even this filtration, but for the fact that, in using the whole fusion, a quantity of bases would thus be brought into the retort, which, even at the low heat required by the distillation, give up their nitric acid, thereby rendering the determination, in its after stages, both more difficult and possibly less exact.

Fluorine.—The fluorine was estimated by the Berzelian method. Though it is far from a good method, care and experience enable one to obtain fairly reliable results. The tendency is toward too high results, because of the difficulty of freeing the calcium fluoride from last traces of alumina and silica; and a better method will probably show even less fluorine to be present in the tourmaline than the insignificant quantity now found.

Ferrous oxide.—Tourmaline, especially the varieties containing lithia and iron, are decomposed by acids with extreme

difficulty. This fact together with the fact that the iron in tourmaline, possibly for some inherent organic reason, as the high and unstable degree of oxidation of the boric acid, oxidizes with unusual ease, has rendered the determination of the condition of this constituent most troublesome On account of its refractory nature, usually not more than 0·2 grams of the finely ground mineral was taken for this determination. Several methods of decomposition were tried without any satisfactory results other than to lead to the conviction that the presence of ferrous iron in large amounts was doubtful, until the digestion of the mineral with hydrofluoric acid, in a sealed platinum crucible over the direct flame, was resorted to with fairly satisfactory and conclusive results.

1st. The mineral was digested with hydrofluoric and sulphuric acids in a sealed platinum crucible in boiling water from one to seven days, a treatment which decomposes most minerals in the course of a few hours. In a few cases complete decomposition seemed to have been effected, in the greater number however it was at the best very incomplete. In no case was more than one per cent of ferrous oxide found, though between thirty and forty experiments were made, and some of the tourmaline analyzed contain as high as eleven per cent of the metal. These attempted determinations were made in a deep heavy platinum crucible of about 60 c.c. capacity. This crucible is made with a flaring mouth into which fits a platinum head secured in place by a gallows screw clamp. Though the platinum joints are ground, a rubber washer is inserted between the cap and the lip of the crucible to ensure tightness. Before sealing the crucible a little carbonate of ammonia is thrown in to expel the air. During the period of digestion the crucible is kept completely immersed in water, so that it is hard to comprehend how the outside air can play any part in the oxidation of the iron. I am accordingly tempted to think that we have here to deal with a very slow reduction of a highly oxidized condition of the boric acid at the expense of which there is a corresponding oxidation of the iron. Either the change goes on very slowly or the explanation proves too much.

2d. From 0·2 to 0·5 grams of the mineral were treated with sulphuric acid—4 parts acid to 1 of water—in sealed glass tubes, from one to four days, at temperatures varying from 150° C. to 250° C. Although the tubes were taken out of the bath frequently and shaken, decomposition, in none of the fifteen attempts, was more than partial. As even the best acid contains organic matter, sometimes in considerable quantities, a higher heat than 200° C. is likely to be attended by a reduction of the acid, thus vitiating the results. This was the method used by Mitscherlich (Journ. prakt. Chemie, lxxxvi, 1)

in establishing the fact that the iron in tourmaline is chiefly ferrous oxide. Rammelsberg, following in his steps, afterwards confirmed the results. But from what I can learn of their determinations they involved a correction which is of such a nature as to render the results worthless as quantitative results. The decomposition being invariably incomplete, the undecomposed material was removed from the glass tube, its amount determined, and a correction made accordingly.

3d. The mineral was also fused with bisulphate and with bifluoride of potash respectively in an atmosphere of carbon dioxide. Though decomposition was usually effected in a couple of hours, the iron was invariably all oxidized. A reduction of the sulphuric acid may be the cause of the result when bisulphate of potash was used. No such explanation avails in the case of the bifluoride fusion.

4th. Convinced, by the summations of some of the analyses, and by comparing the loss on ignition with the corresponding direct water determinations, that the iron in tourmaline must be there, in large part at least, in the ferrous condition, I finally heated the mineral with hydrofluoric and sulphuric acids in the closed platinum crucible over the direct flame, thus digesting at a moderately high temperature and a correspondingly high pressure, and at the same time securing a constant agitation of the powdered mineral—a condition of vital importance. In these determinations a thin lead washer replaced the rubber. A half hour, with these conditions, usually sufficed to bring about complete decomposition. The crucible was cooled in an atmosphere of carbon dioxide and the iron determined in the ordinary way with a permanganate solution. Fair results were obtained, such as to indicate that the iron in tourmaline is there chiefly in the ferrous condition.

Alkalies.—Several vain attempts were made to decompose the tourmaline with hydrofluoric and sulphuric acids. As showing the refractory nature of the mineral the following is a case in point: One gram of the pale green Auburn variety, after being ignited, was evaporated to dryness with 20 c.c. of hydrofluoric acid five times, and yet left an insoluble residue of 0·473 grams. The Lawrence Smith method was finally adopted and with highly satisfactory results. The only precautions necessary are that the mineral be finely powdered and that the mixture with ammonium chloride and calcium carbonate be intimate, which latter condition is only to be secured by grinding the several ingredients together. When these conditions are what they should be, there is no trouble in bringing about complete decomposition in the course of an hour's gentle ignition. After the alkalies have been leached out with water the residue should of course be treated with acid to test the com-

pleteness of the disintegration. In the case of the tourmalines, with their low silica percentages, the solution is usually complete if the decomposition has been complete. After the alkalies have been freed from the other bases by the usual well-known methods, though the greater part of the boric acid will have been driven off by the repeated evaporations, more or less may remain. This residual is removed by two or three evaporations with methyl alcohol. The separation of lithia from the other alkalies was made by the Gooch method, i. e., by boiling the mixed chlorides in amyl alcohol, and the further separation of the potash and soda effected after the usual manner.

Silica.—On the strength of the belief that tourmaline sometimes contained fluorine in considerable amounts, the silica was at first estimated by precipitating it with carbonate of ammonia. When the bases, thrown out by this reagent, are so in excess of the silica as they are in tourmaline, its precipitation is quite easy and quantitative. Nevertheless, when the method was used of duplicate determinations, the higher was taken in the summation of the analysis. (Save where the silica is greatly in excess of the bases thrown down by ammonium carbonate, the addition of zinc or like compounds, as is commonly recommended, is wholly unnecessary. In fact, even in dealing with such minerals as the lepidolites, which contain about fifty per cent of silica and less than thirty of alumina, the addition of zinc compounds gives no better results than can be obtained by simple evaporation with carbonate of ammonia, the evaporation being repeated several times.)

So soon as it became evident that the amount of fluorine, if present at all, was so small that its influence in carrying off silica (the amount of silica carried off by fluorine on evaporating a soda fusion with hydrochloric acid is but a small part of the tetrafluoride equivalent) could be neglected, the ordinary method of separation was employed. In all cases the silica was corrected by evaporation with hydrofluoric acid.

Alumina.—The only point worthy of mention in this connection is the necessity of testing the alumina for the silica which it frequently contains. This is usually done by fusing the ignited oxides with bisulphate of potash. But when they amount to as much as they do in the tourmaline a carbonate of soda fusion works more satisfactorily. It can be continued longer and at a higher temperature. This fusion is readily converted into a sulphate fusion and the desired silica separation thus accomplished. As regards other determinations nothing in particular need be said.

Analyses.

Analyses have been made of material from the following localities: Auburn, Rumford, and Paris, Maine; Calhao, province of Minas Geraes, Brazil; Dekalb, Gouverneur and Pierrepont, N. Y.; Hamburg, N. J.; Orford, N. H.; Monroe and Haddam, Ct.; Stony Point, N. C., and Nantic Gulf, Baffin's Land. These represent well the variations in physical properties and chemical composition which characterize the different varieties of tourmaline. The results of these analyses are grouped for the sake of compactness. The tourmalines from Maine and Brazil are thrown together according to localities. Those from other localities are roughly grouped on the basis of their composition.

Maine.—These tourmalines occur in veins of albitic granite, the chief constituents of which are quartz, albite and muscovite, with lepidolite and beryl as important accessories.

Auburn.—A. Colorless to pale green crystals, some of which were tinged pink and blue; infusible. G. 3·07. *B.* Light green fragile crystals, infusible. *C.* Dark green massive tourmaline, fuses with difficulty. *D.* Massive black tourmaline, easily fusible. G. 3·19.

	A			B			C			D		
	I.	II.		I.	II.		I.	II.		I.	II.	
SiO_2	38·14	—	38·00	37·85	—	37·80	36·26	—	36·98	34·99	—	34·87
Al_2O_3	39·60			37·73			36·68			33·96		
Fe_2O_3	·30			·42			·15			none		
FeO	1·38	41·37–41·48		3·88	42·37–42·54		7·07	44·65–44·73		14·23	49·76–49·79	
TiO_2	none			none			none			?		
P_2O_5	trace			trace			trace			trace		
MnO	1·38			·51			·72			·06		
CaO	·43			·49			·17			·15		
MgO	trace			·04			·16			1·01		
Li_2O	1·34			1·34			1·05			trace		
Na_2O	2·36			2·16			2·88			2·01		
K_2O	·27			·62			·44			·34		
H_2O	4·16	4·06-4·26		4·18	4·16-4·20		4·05	4·00-4·11		3·62	3·56-3·68	
B_2O_3	10·25	10·15-10·34		10·55			9·94	9·83-10·04		9·63	9·44-9·82	
F	·62	—	·72	·62	—	·72	·71	—	·80	none		
	100·23			100·39			100·28			100·00		
less oxy.	·26			·26			·30					
	99·97			100·13			99·98					

The material for the above analyses was received from Mr. N. H. Perry, of South Paris, Maine.

Rumford. A. Massive, rose-colored, infusible. G. 2·997. *B.* Massive, dark green, fuses with difficulty.

Paris, Black Mt. Massive, black, powder bluish, easily fusible.

	A			B			Paris.	
		I.	II.		I.	II.	I.	II.
SiO_2	38·07	—	38·02	36·53	—	36·42	35·03	34·99–35·06
Al_2O_3	42·24			38·10			34·44	
Fe_2O_3	—			none			1·13	
FeO	·26	42·44–42·64		6·43			12·10	
P_2O_5	none			trace			trace	
MnO	·35			·32			·08	
CaO	·56			·34			·24	
MgO	·07			none			1·81	
Li_2O	1·59			·95			·07	
Na_2O	2·18			2·86			2·03	
K_2O	·44			·38			·25	
H_2O	4·26	4·25–4·28		3·52	3·44–3·60		3·69	3·63–3·75
B_2O_3	9·99	9·85–10·13		10·22	10·03–10·41		9·02	8·92–9·12
F	·28			·16			none	
	100·29			99·81			99·89	
Less oxygen	·12			.07				
	100·17			99·74				

For the Rumford material I am indebted to Mr. E. M. Bailey, of Andover, Maine. The Paris tourmaline was kindly furnished me out of the National Museum collection.

In connection with the Maine tourmaline the following interesting alteration products were studied. *A.* An alteration from the light green Auburn (B) variety. *B.* Flesh-colored alteration from the Rumford locality. *C.* An alteration from the Hebron rubellite.

	A	B	C
SiO_2	—	53·03	43·90
Al_2O_3	—	31·67	38·71
Fe_2O_3	—	·51	·58
FeO	—	—	·25
MnO	—	trace	·04
CaO	—	trace	·41
MgO	—	trace	·05
Li_2O	2·86	·26	—
Na_2O	2·16	·54	1·05
K_2O	9·64	9·44	10·92
H_2O	—	4·80	4·25
B_2O_3	trace	trace	trace
F	—	trace ?	none
		100·25	100·16

While the light green Auburn tourmaline were mostly translucent crystals, a few were found, which, having become partially opaque, had assumed a micaceous structure. With scant material but the above partial analysis was possible. The results indicate a change in the direction of lepidolite.

The Rumford alteration product was examined microscopically by Mr. J. S. Diller, who observed as follows: "under the microscope it is seen to be composed of two minerals most

thoroughly intermingled in nearly equal proportions. One of these minerals is micaceous in structure, with strong double refraction like damourite, which it closely resembles in general appearance. The other mineral is clear, colorless and apparently monoclinic, with a rather low index of refraction and moderately intense double refraction."

While the Hebron rubellite alteration product retains its crystalline form, its material is altered into a softer mineral of an opaque talcose appearance. The analysis shows the change to be toward damourite (F. W. Clarke, this Journal, Nov., 1886), and not lepidolite as has been supposed in this case.

Brazil, Calhas, Province of Minas Geraes. The association of these tourmalines I was unable to find out. From their composition however it is probable that it does not differ greatly from that of the Maine varieties. The specimens analyzed were from the hands of Mr. G. F. Kunz. *A.* The pink, almost colorless center of crystals having a green border, infusible, G. 3·028. *B.* Pale green, like the border of B, infusible. *C.* Olive green, fusible in very thin splinters. *D.* Black, in thin splinters a smoky blue green, fuses easily, G. 3·20.

	A			B			C			D		
		I.	II.		I.	II.		I.	II.		I.	II.
SiO_2	37·19	—	37·12	37·39	—	37·31	36·91			34·63	—	34·50
Al_2O_3	42·43			39·65			38·13			32·70		
Fe_2O_3	none			·15			·31			·31		
FeO	·52	42·94–43·08		2·29	42·30–42·38		3·19			13.69		
P_2O_5	none			trace			·11			none		
MnO	·79			1·47			2·22			·12		
CaO	·57			·49			·38			·33		
MgO	none			none			·04			2·13		
Li_2O	1·73			1·71			1·61			·08		
Na_2O	2·24			2·42			2·70			2·11		
K_2O	·23			·25			·28			·24		
H_2O	3·90	3·86–3·93		3·63	3·60–3·66		3·64			3·49	3·42–3·56	
B_2O_3	10·06	9·96–10·16		10·29	10·10–10·49		9·87	9·85–9·88		9·63	9·55–9·70	
F	trace ?			·32	—	·41	·14	—	·17	·06	—	·10
	99·66			100·06			99·53			99·52		
Less oxygen				·13			·06			·02		
				99·93			99·47			99·50		

Dekalb, St. Lawrence Co., N. Y. Colorless to light brown translucent crystals, in calcite, with quartz and titanic oxide inclusions, easily fusible, G. 3·085.

Gouverneur, St. Lawrence Co., N. Y. Brown, massive, associated with calcite. Easily fusible.

Hamburg, N. J. Large cinnamon-brown crystals, associated with quartz and colorless mica in calcite, abounding in inclusions of small black scales of titanic oxide. Easily fusible.

	Dekalb.			Gouverneur.			Hamburg.		
		I.	II.		I.	II.		I.	II.
SiO_2	36·88			37·39	37·33–37·45		35·25		
Al_2O_3	28·87			27·79			28·49		
Fe_2O_3	—			·10			none		
FeO	·52			·64			·86		
TiO_2	·12			1·19			·65		
P_2O_5	undet.			none			trace		
MnO	none			none			none		
CaO	3·70			2·78			5·09		
MgO	14·53			14·09			14·58		
SrO	trace			trace			trace		
BaO	none			none			none		
Li_2O	trace			trace			trace		
Na_2O	1·39			1·72			·94		
K_2O	·18			·16			·18		
H_2O	3·56	3·55–3·57		3·83	3·77–3·89		3·10	3·02–3·18	
B_2O_3	10·58	10·46–10·70		10·73	10·63–10·83		10·45		
F	·50			trace ?			·78		
	100·83			100·42			100·37		
Less oxygen	·21						·33		
	100·62						100·04		

For the Dekalb and Hamburg tourmaline I am greatly indebted to Mr. G. F. Kunz. The Gouverneur material was from the National Museum collection.

From the large amount of titanic oxide found in the Gouverneur specimen, it was feared that it might be there as an impurity. Mr. Diller kindly examined a section microscopically and found it, on the contrary, to be quite free from inclusions of any kind. Specimens, from other Gouverneur localities, viz: from the town of Gouverneur itself and from Reese's farm, seven miles to the northward, were also found to contain the oxide in large amounts.

Orford, N. H. Dark brown crystals in chloritic schist. Easily fusible.

Monroe, Ct. Dark brown crystals in chloritic schist. Easily fusible.

	Oxford.			Monroe.	
		I.	II.		
SiO_2	36·66			36·41	
Al_2O_3	32·84			31·27	
Fe_2O_3	none			none	
FeO	2·50			3·80	
TiO_2	·23			1·61	
P_2O_5	none			trace	
MnO	trace			trace	
CaO	1·35			·98	
MgO	10·35			9·47	
Sr,O	trace			trace	
BaO	none			none	
Li_2O	trace			none	
Na_2O	2·42			2·68	
K_2O	·22			·21	
H_2O	3·78	3·77–3·79		3·79	3·76–3·82
B_2O_3	10·07	9·86–10·28		9·65	9·57–9·73
F	trace			none	
	100·42			99·87	

The Orford material was received from Mr. C. H. Hitchcock, the Monroe specimen came from the National Museum Collection. The schistose gangue, in which the tourmaline from Orford and Monroe are imbedded is of particular interest, and was studied microscopically as well as chemically, in the hope that it might throw light on the genetic relations of magnesian tourmaline. The microscopic work, which was of special importance was kindly undertaken by Mr. J. S. Diller. The following are the results of partial chemical analysis :—

	Orford.	Monroe.
SiO_2	27·18	43·30
Al_2O_3	33·10	27·44
CaO	·19	1·96
MgO	28·09	19·22
Na_2O	undet.	1·47
K_2O	undet.	·60
Ign.	11·75	7·45
	100·31	101·44

While Mr. Diller found the Orford matrix to be essentially chlorite, in agreement with the results of chemical analysis, the gangue rock of the Monroe tourmaline turned out to be particularly interesting.

Of this Mr. Diller says, "this light gray glittering rock is composed chiefly of biotite, chlorite and a light colored mineral which may possibly be zoisite. The biotite is very dark and apparently uniaxial and negative, with all the other physical properties of the species. The chlorite is much paler than the biotite, and is of a greenish color. It is distinctly biaxial, with a small optic angle, and positive. The relation of the chlorite to the biotite is readily seen in the thin sections where it evidently is derived from the latter by a process of alteration. An interesting feature is that in the immediate vicinity of the imbedded tourmaline the biotite is all changed to chlorite, and is arranged with its foliae approximately perpendicular to the crystallographic planes of the tourmaline, against which it impinges. The chlorite completely envelopes the tourmaline and the other portions of the hand-specimen are made up chiefly of biotite and the zoisitic mineral, with a small proportion of chlorite. This variation in the mineralogical composition of the hand-specimen readily explains the discrepancy there at first appeared to be between the results of chemical analysis and my observations." That the analysis represents a portion of the rock rich in chlorite and poor in biotite, the high magnesia and low alkalies plainly show. The relation existing between the biotite, chlorite and tourmaline in this Monroe matrix is instructive, indicating, as suggested, the transition to be from the mica through the chlorite to the tourmaline.

Pierrepont, St. Lawrence Co., N. Y. Perfect black crystals, in calcite, fuses easily. G. 3·08.

Nantic Gulf, Cumberland, Baffin's Land. A large black crystal, easily fusible. G. 3·095.

Stony Point, Alexander Co., N. C. Perfect medium-sized black crystals, with implanted crystals of quartz; associated minerals chiefly quartz, muscovite, apatite, rutile, beryl and spodumene, fuses easily. G. 3·13.

Haddam, Ct. Black crystals in quartz and feldspar, powder blue black, easily fusible.

	Pierrepont.		Nantic Gulf.		Stony Pt.		Haddam.	
	I.	II.	I.	II.	I.	II.	I.	II.
SiO_2	35·61		35·34		35·56		34·95	
Al_2O_3	25·29		30·49		33·38		31·11	
Fe_2O_3	·44		none		none		·50	
FeO	8·19		8·22		8·49		11·87	
TiO_2	·55		·40		·55		·57	
P_2O_5	trace		none		?		trace	
MnO	trace		trace		·04		·09	
CaO	3·31		2·32		·53		·81	
MgO	11·07		7·76		5·44		4·45	
SrO	none		trace		none		none	
BaO	?		?		none		none	
Li_2O	trace		trace		trace		trace	
Na_2O	1·51		1·76		2·16		2·22	
K_2O	·20		·15		·24		·24	
H_2O	3·34	3·30–3·37	3·60	3·53–3·67	3·63	3·57–3·69	3.62	3·58–3·66
B_2O_3	10·15	10·00–10·31	10·45	10·30–10·60	10·40		9·92	9·74–10·10
F	·27		none		none		none	
	99·93		100·49		100·42		100·35	
Less oxygen,	·11							
	99·82							

Mr. W. E. Hidden very kindly furnished the Stony Point material. For the other specimens I am indebted to the National Museum collection. The gravity determinations of the Pierrepont, Stony Point and Nantic Gulf tourmaline were kindly made by Dr. William Hallock.

From the above analyses it is at once apparent that we have three types to deal with, lithia, iron and magnesia tourmaline respectively, with an indefinite number of intermediate products. As an aid to comparison I have brought these results together in the following table, arranging them so as best to show how these types graduate from one into the other, beginning with the lithia tourmaline and passing from them through the iron varieties to those of the purer magnesian type. The iron tourmaline appears to be the connecting link.

	B_2O_3	SiO_2	Al_2O_3	Fe_2O_3	FeO	TiO_2	P_2O_5	MnO	CaO	MgO	Li_2O	Na_2O	K_2O	H_2O	F	Sum	Ign.
Rumford A	9·99	38·07	42·24	----	·26	none	none	·35	·56	·07	1·59	2·18	·44	4·26	·28	100·17	4·35
Brazil A	10·06	37·19	42·43	none	·52	?	none	·79	·57	none	1·73	2·24	·23	3·90	tr.?	99·66	4·10
Auburn A	10·25	38·14	39·60	·30	1·38	none	tr.	1.38	·43	none	1·34	2·36	·27	4·16	·62	99·97	4·09
Brazil B	10·29	37·39	39·65	·15	2·29	?	tr.	1·47	·49	none	1·71	2·42	·25	3·63	·32	99·93	----
Auburn B	10·55	37·85	37·73	·42	3·89	none	tr.	·51	·49	·04	1·34	2·16	·62	4·18	·62	100.13	----
Brazil C	9·87	36·91	38·13	·31	3·19	?	.11	2·22	·38	·04	1·61	2·70	·28	3·64	·14	99·47	3·62
Rumford B	10·22	36·53	38·10	none	6·43	?	tr.	·32	·34	none	·95	2·86	·38	3·49	·16	99·71	3·31
Auburn C	9·94	36·26	36·68	·15	7·07	none	tr.	·72	.17	·16	1·05	2·88	·44	4·05	·71	99·98	----
Paris	9·02	35·03	34·44	1·13	12·10	?	tr.	·08	.24	1·81	·07	2·03	·25	3·69	none	99·89	2·30
Auburn D	9·63	34·99	33·96	none	14·23	none	tr.	·06	.15	1·01	tr.	2·01	·34	3·62	none	100·00	2·17
Brazil D	9·63	34·63	32·70	·31	13·69	?	none	·12	.33	2·13	·08	2·11	·24	3·49	·06	99·50	2·19
Haddam	9·92	34·95	31·11	·50	11·87	·57	tr.	·09	.81	4·45	tr.	2·22	·24	3·62	none	100·35	2·41
Nantic Gulf	10·40	35·56	33·38	none	8·49	·55	?	·04	.53	5·44	tr.	2·16	·24	3·63	none	100·42	2·88
Stony Pt.	10·45	35·34	30·49	none	8·22	·40	none	tr.	2·32	7·76	tr.	1·76	·15	3·60	none	100·49	2·86
Pierrepont	10·15	35·61	25·29	·44	8·19	·55	tr.	tr.	3·31	11·07	tr.	1·51	·20	3·34	·27	99·82	2·69
Monroe	9·65	36·41	31·27	none	3·80	1·61	tr.	tr.	·98	9·47	none	2·68	·21	3·79	none	99·87	3·59
Orford	10·07	36·66	32·84	none	2·50	·23	tr.	tr.	1·35	10·35	tr.	2·42	·22	3·78	tr.?	100·42	----
Gouverneur	10·73	37·39	27·79	·10	·64	1·19	none	none	2·78	14·09	tr.	1·72	·16	3·83	tr.?	100·42	----
Dekalb	10·58	36·88	28·87	none	·52	·12	?	none	3·70	14·53	tr.	1·39	·18	3·56	·50	100·62	----
Hamburg	10·45	35·25	28·49	none	·86	·65	tr.	none	5·09	14·58	tr.	·94	·18	3·10	·78	100·04	----

As the outcome of his work, Rammelsberg concludes that all tourmaline may be referred to the following silicate types: R'_6SiO_5, R''_3SiO_5, and R''_2SiO_5, in which R′=H, Li, Na and K, R″=Mg, Ca, Fe, and Mn and R‴=Al and B, making boric acid and alumina equivalent. He groups them in two classes: I, iron-magnesian tourmaline, represented by the formula

$$m\left\{\begin{matrix} R'_6SiO_5 \\ 3R'''_2SiO_5 \end{matrix}\right\} + n\left\{\begin{matrix} R''_3SiO_5 \\ 3R'''_2SiO_5 \end{matrix}\right\}$$

R‴=B : 2Al and II, lithia tourmaline referred to the formula

$$m\left\{\begin{matrix} R'_6SiO_5 \\ 8R'''_2SiO_5 \end{matrix}\right\} + n\left\{\begin{matrix} R''_3SiO_5 \\ 8R'''_2SiO_5 \end{matrix}\right\} \text{ where } R'''=B:3Al,$$

with the following special formulæ: $R'_2R''_2Al_4B_2Si_4O_{20}$ for the more purely magnesian varieties; $R'_{10}R''_4Al_{12}B_6Si_{12}O_{60}$ for the purer iron varieties, and for the lithia tourmaline $R'_6Al_{12}B_4Si_9O_{45}$, and other complications for those lithia varieties containing iron.

Attention has been called to the weak points in Rammelsberg's analyses; but, for the sake of emphasis, I refer again to his method of determining the water and what depends on it. He assumes that the fluorine is driven off quantitatively on ignition, carrying with it silicon as the tetrafluoride. This assumption is a questionable one. A half hour's blasting would seem to be sufficient to drive off the water, but it was repeatedly observed that where the tourmaline contained fluorine. further blasting, after the water was presumably all expelled, was invariably accompanied by a small loss. This after loss was probably fluorine in some of its silicon compounds, as experiments made it clear that boric acid is driven off by no amount of blasting. While making this correction for fluorine, the oxidation of the iron is wholly ignored. If anything was noticeable in the ignition of tourmaline it was the apparent ease with which the iron oxidized. In the above table the loss on ignition is given in many cases. Comparing this loss with the direct determinations of water, at the same time noting the amounts of iron contained in the tourmaline in question, one is forced to conclude that the oxidation of the iron plays an all-important role here, in diminishing the loss by ignition by the amount required to convert it into ferric oxide. If we take Rammelsberg's ignition results* and make the more justifiable correction for the oxidation of the iron, setting aside the fluorine correction, we would have more concordant results to deal with; results, moreover, which agree closely with the direct determinations of water. But if the percentages repre-

* Pogg., lxxx, 449; lxxxi, 1.

senting water be low, those of boric acid, where estimated by difference, ought to be correspondingly high, and so they are in a few cases In the greater number of analyses, however, they are unaccountably low, unless we suppose, as I am inclined to, that the silica determinations were high, representing in some cases, besides actual silica, more than a per cent of impurities. If all this be true, in working out his ratios, Rammelsberg found in water and boric acid two variables instead of the two constants that they probably are, and one need not wonder that he found it difficult to discover unity in his analyses.

It is scarcely necessary to say that certain constituents found in tourmaline are non-essential, but have been thrust upon them by their associates. The idea that a tourmaline must have its fluorine was long since exploded.

If we study the essential constituents in the light of their molecular or atomic ratios, we will find some very interesting relations. The ratios of certain elements are constants in all varieties of tourmaline. $Si : B : H : O = 1 : \frac{1}{2} : \frac{2}{3} : 5{\cdot}2$. All the other constituents are variable and within rather indefinite limits. Considered individually they are enigmas. If, however, the bases, including hydrogen, be reduced to a common univalent basis and be consolidated, the results fall into line with the above ratios. This reduction may be made in either one of two ways, and with almost equally good results. In the table of the ratios of constants given below it will be noticed that the oxygen ratio is invariably slightly in excess of the amount necessary to the silicon and boron even though we assume both the SiO_4 group as we certainly must, and the group BO_2 as is also necessary if we would give account for the oxygen. This small residual is to be disposed of. It can be done by postulating either an Al=O or the O–H group. Both hypotheses have been used in constructing the following table. $R^{(1)}$ is the univalent equivalent of the bases with the oxygen excess incorporated in an Al=O group, $R^{(2)}$ the univalent equivalent of the bases on the basis of an assumed O–H group. The table is given in full that the extent of the variations, from what seem to be simple ratios, may in no wise be concealed, as is often the case, when averages are given. The hydrogen ratio, though already included in R, is given by itself, being one of the constants. For much the same reason the alkali ratios are also given, although here the constancy would seem to be limited to a type. This at least appears to be true for the iron and lithia varieties.

	Si	B	$R(^1)$	$R(^2)$	O	H	Alk.
Rumford A.	1	·46	4·48	5·01	5·18	·74	·28
Brazil A.	1	·47	4·45	5·12	5·26	·70	·31
Auburn A.	1	·46	4·43	4·83	5·10	·72	·28
Brazil B.	1	·47	4·50	4·92	5·17	·66	·31
Auburn B.	1	·48	4·48	4·80	5·11	·71	·30
Brazil C.	1	·45	4·42	4·93	5·15	·66	·32
Rumford B.	1	·48	4·44	4·95	5·20	·64	·30
Auburn C.	1	·46	4·50	4·99	5·20	·74	·28
Paris.	1	·45	4·47	5·09	5·21	·70	·12
Auburn D.	1	·48	4·50	5·01	5·21	·70	·12
Brazil D.	1	·48	4·50	5·02	5·21	·68	·13
Haddam.	1	·50	4·51	5·00	5·24	·69	·12
Nantic Gulf.	1	·51	4·52	5·00	5·25	·68	·12
Stony Pt.	1	·51	4·19	5·01	5·41	·68	·10
Pierrepont.	1	·51	4·52	4·77	5·13	·63	·09
Monroe.	1	·46	4·43	4·89	5·12	·69	·15
Orford.	1	·48	4·48	4·99	5·20	·68	·13
Gouverneur.	1	·50	4·51	4·73	5·10	·68	·10
Hamburg.	1	·51	4·50	5·08	5·30	·59	·06
Dekalb.	1	·50	4·51	5·08	5·29	·66	·08
	1	·48	4·47	4·96	5·20	·67	

Except in two or three cases the ratios of $Si : B : R(^1) : O$ approximate closely $1 : \frac{1}{2} : \frac{3}{2} : 5$. The oxygen, in excess of the amount exactly represented by the ratio (5), having been absorbed in an Al=O group. These ratios give as a general tourmaline formula the simple boro-orthosilicate $R_9BO_2{}2SiO_4$, which resolves itself into the graphic formula

$$R\overset{\diagup BO_3}{=SiO_4}\diagdown R$$
$$R\underset{\diagdown}{=}SiO_4$$

The R_9 includes the constant $H=R_3^1$ (Li, Na, K), varying between the limits R_0^1 and R_3^3, (Ca. Mg) varying from R_0 to R_3, Fe varying from R_0 to R_3^1 and (Al, Al=O) varying from R_4 to R_7. On the other hand the ratios $Si : B . R(^2) : O$ are about as $1 : \frac{1}{2} : 10 : 5{\cdot}20$, which would give the equally simple general formula $R_{10}BO_2{}2SiO_4$, where R_{10} includes the above constant and variables excepting that OH replaces the Al=O group and Al accordingly varies between the limits R_5 and R_8. If we expand, in order to bring out the hydroxyl ratio, we have $12SiO_4$, $6BO_3$, $R_{22}H_5(OH)_3 = Si : B : R : O = 1 : \frac{1}{2} : 5 : 5{\cdot}25$.

Between these two views there are at present no means at hand of deciding. Could we find out that the water is not all driven off at the same temperature or something of the kind, the knowledge would favor the latter assumption.

Experiments to this end are desirable. But whichever postulate we make, the following special formula may be taken as representing typical compounds of the three varieties:

I. Lithia tourmaline $12SiO_2$, $3B_2O_3$, $4H_2O$, $8Al_2O_3$, $2(NaLi)_2O$.
II. Iron tourmaline $12SiO_2$, $3B_2O_3$, $4H_2O$, $7Al_2O_3$, $4FeO$, Na_2O.
III. Magnesian tourmaline $12SiO_2$, $3B_2O_3$, $4H_2O$, $5Al_2O_3$, $\frac{2}{3}MgO$, $\frac{2}{3}Na_2O$.

Calculated.	I.	II.	III.
B_2O_3	11·00	10·18	10·90
SiO_2	37·70	34·89	37·38
Al_2O_3	42·75	34·59	26·49
FeO	——	13·95	——
MgO	——	——	19·31
Li_2O	1·57	——	——
Na_2O	3·21	2·90	2·18
H_2O	3·77	3·49	3·74
	100·00	100·00	100·00

On comparing the theoretical composition of the above types with the results of analysis, they will be found to agree as closely as could be expected, at least in values of the constants. The boric acid found invariably falls short of the theory. This is to be expected. The analyses do not represent ideal compounds, but are made of material more or less impure and the case would be very exceptional where the impurity tended to raise and not lower the percentage of boric acid.

In some of the above formulas the group BO_2 has been assumed because the oxygen ratio demanded it. As has already been suggested the ease with which the iron oxidizes and the mysterious manner in which this change takes place, under conditions when we would suppose it to be impossible, possibly point toward a higher degree of oxidation than the more common B_2O_3. As the result of a slow molecular rearrangement the one is oxidized at the expense of the other. Such a change is, I believe, not without its analogies. Certain borates, where the assumption of an even higher oxide is thought necessary, on being heated give borates of a lower order.

Notes.—The question of color is an interesting one, particularly when the varying colors of the lithia tourmaline are concerned. For, while the color of the iron and magnesian varieties depends on the amount of iron present and ranges from the colorless Dekalb through all the shades of brown to the Pierrepont black, the lithia tourmaline, containing more or less manganese, give us the red, green and blue, as well as the colorless varieties, the shades of color not depending on the absolute amount of manganese present but rather on the ratios existing between that element and the iron. When the ratios of Mn : Fe approximate = 1 : 1 we have the colorless, pink or very pale green tourmaline. An excess of manganese produces the red

varieties. On the other hand if the iron be in excess the result is the various shades of green and blue.

As regards fusibility, the lithia tourmalines which are free from both iron and magnesia are infusible. The presence of either or both of these elements brings with it a degree of fusibility increasing with their increase till we find in those tourmalines containing much of either or both constituents easily fusible minerals.

The titanic oxide associated with the Hamburg and Dekalb tourmaline attracted special attention because of its form. Having been examined chemically it was studied microscopically by Mr. J. S. Diller, who observed as follows: "The small iron black scales with a rather brilliant metallic luster are cleavable into very thin folia, the thinnest of which, under the microscope, are perfectly opaque. In reflected light these lamellæ show three systems of cleavage planes, traces of which, upon the plane of foliation, intersect at an angle of 60°. The cleavage planes make a large angle with the plane of foliation and it is evident that this mineral is rhombohedral in crystallization. It is infusible on very thin edges and does not become magnetic when heated. By this means it is distinguished from hematite and ilmenite. From its physical properties alone I should conclude that it is a member of the ilmenite series rich in oxide of titanium. As analysis shows it to be essentially titanic oxide, it becomes of special interest. In the first place it is the extreme member of the ilmenite series and in the second place it is a new form of titanic oxide, which is thus shown to be tetramorphic."

Laboratory U. S. Geol. Survey, Washington, August 31, 1887.

Art. IV.—*On the different types of the Devonian System in North America;* by Henry S. Williams.*

The sections of the Devonian rocks in North America present at least four distinct types of stratigraphy in their outcrops in different parts of the continent. The four areas blend somewhat at their borders, but in their central sections are very distinct.

The four areas may be called the

(1) *Eastern Border Area*, including the outcrops of Gaspé, New Brunswick, Maine, and other places in Northern New England;

* Read at the New York meeting of the American Association for the Advancement of Science, August, 1887, and constituting a part of a preliminary report on the Devonian to the American Committee of the International Congress of Geologists.

(2) The *Eastern Continental Area*, including the New York and Appalachian tracts as far south as West Virginia, and extending northwestward into Canada West and Michigan;

(3) The *Interior Continental Area*, typically seen in Iowa and Missouri, extending into Illinois and Indiana, and probably northward toward the valley of the Mackenzie River; and

(4) The *Western Continental Area*, best known through Hague and Walcott's studies of the Eureka, Nevada, sections.

Each of these four areas presents sections of the Devonian, which in all the details of their stratigraphical, lithological and paleontological composition are different from each other.

The Eastern Border Area.

The typical eastern border section, as seen at Gaspé, is a heavy series of arenaceous shales, sandstones and conglomerates, gray, drab and red in color, of some 7,000 feet thickness. It lies upon 2,000 feet of limestone, which holds in the upper part fossils of upper Silurian age. These are regarded by Billings as of Helderberg types. The first thousand feet of the sandstone shows a rich flora, and, by some traces of invertebrate fossils, is known to date back as early as the age of the Oriskany sandstone. The first 5,000 feet of the sandstone represents the interval from the top of the Silurian to the top of the Chemung series of the New York section, and the terminal 2,000 feet may represent the Catskill series of New York. (See Logan's Report upon the Gaspé section in "Geology of Canada," 1863, p. 390, etc.) The greater part of this section contains very few fossils, and these are mainly plant remains. In the continuation of the Gaspé sandstones on the Bay de Chaleur the lower and upper beds, as I am informed by Sir William Dawson, are not only distinguished by characteristic plants but also by a rich fish fauna resembling that of Scotland, and divisible into a lower zone with Cephalaspis, Coccosteus, etc., and an upper with Pterichthys. On tracing the outcrops westward across Maine and Northern New England, the coral-bearing limestones of the lower Devonian appear, indicating a changed condition of the seas on approaching the old Archæan axis on the westward, but the outcrops, as well as the identity of the fossils, are too indefinite to give a clear idea of the relation of this border region to the better known sections south of the Adirondacks and farther west in New York State.

The Eastern Continental Area.

The second area, the eastern continental, is represented typically in New York State. From there it has been traced downward along the Appalachians as far as to West Virginia (the Tennessee section assuming a closer relation to the interior

area), and northwestward in Ohio, Canada West and Michigan. On the western side of the Cincinnati axis the section is intermediate, but presents closer relations with those of the interior than with the typical New York section.

In New York there is a full series of temporary stages of deposition each having its characteristic lithological composition and each holding its distinctive fauna. The lower Helderberg limestones were followed, in this area, by a deposit of coarse sand which is thicker and more prominent in the eastern and southeastern part of the region, there attaining several hundred feet in thickness, but thins out toward the northwest, and fails altogether, both in the extreme southwestern and in the extreme northwestern extension of the area. This is the Oriskany sandstone, marked by a few large and well-defined Brachiopods. The Oriskany stage is generally more or less calcareous, and runs up into calcareous shales and grits along the northeastern border of the area. These latter are the Cauda-galli and Schoharie grits of the New York section. They are followed above by the Onondaga and Corniferous limestones, averaging less than a hundred feet in thickness, but reaching three hundred feet thickness, or more, in some parts of New York and in Michigan.

In this eastern continental area there was evidently some relationship between the sandy deposits beginning in the Oriskany and the calcareous deposits typically represented in the Onondaga and Corniferous limestones; for we find in the northwestern part of the area the sandstones thinning out to almost nothing, while the limestones reach their greatest thickness, and in the eastern and more southern parts of the area the sandstones reach their greatest thickness, while the limestone dwindles and in some parts has not been distinguished at all. The limestone is rich in corals, and in some layers, has abundant Brachiopods; the latter are types of wide geographical distribution, and, in the more common forms, such as *Strophomena rhomboidalis* and *Atrypa reticularis*, are species of long geological range. Some of the corals, too, have a long range in the western continental section, appearing in the upper part of the Nevada limestone, according to Mr. Walcott.

In New York the next lithological stage of the Devonian is a series of shales, often beginning and terminating in black and sometimes partly calcareous shales; but in the central part of the section, gray, soft argillaceous shales, temporarily calcareous in places, and holding a rich and abundant fauna, constitute the Hamilton stage. The Hamilton also shows tendency to be more calcareous westward and more arenaceous in the eastern outcrops, and the sandstones and arenaceous shales are thicker and predominate in the Pennsylvania, Maryland and Virginia sec-

tions, while the argillaceous and calcareous shales are more conspicuous in New York, Ohio, Canada West and Michigan. A thousand feet may be taken as an average for the thickness, including the two terminal black shales, though some of the Appalachian sections double this thickness. In our accepted classification the upper, Genesee black shale is grouped with the Hamilton, but, as I have shown elsewhere, there are good reasons for drawing the distinctive line, separating middle and upper Devonian, below rather than above the Genesee shale.

Above the Hamilton stage a period of deposition of arenaceous shales and sandstones prevailed all over this eastern area, called the "Chemung Period" by Dana, and divided into the Portage and Chemung stages. The deposits attain a thickness of two or three thousand feet in New York and Northern Pennsylvania, and farther south are represented by 5,000 feet of sandy deposits, coarser toward the top, and with occasional gravel conglomerates. This series of deposits is characteristic of the eastern area, and is not recognized in the central or western areas. It is linked by its flora with the eastern border sections, and by its fauna is recognized as intimately associated with the upper Devonian deposits of North Devonshire in England.

The faunas of the upper Devonian change rapidly in composition on passing westward from the Appalachian ridges, and the pure Chemung type is scarcely recognized west of western New York and Pennsylvania, although some of its species are seen in the Iowa and Nevada sections. Passing into Ohio, Canada West and Michigan, the upper part of the Devonian assumes a distinct type, which is more closely allied with that of the Indiana and Illinois sections. It appears to be a prevalence of the conditions expressed in the Genesee shales and associated Portage shales and sandstones of New York, with the failure of the Chemung rocks and fauna, running up into shales and sandstones of the Waverly and closing with conglomerates. The more eastern sections, after the Hamilton, run up into sandstones, red and gray shales, sandstones of considerable thickness, and conglomerates, and present no trace of any marine fauna intermediate between the Chemung and the Carboniferous. As we approach the Ohio border going westward the Chemung fauna also fails, and the Waverly follows the Hamilton with only the fauna of the black shales intervening.

In the eastern part of New York, Pennsylvania and southward, the coarse sands and conglomerates with red and green shales, prevail after the Hamilton stage, reaching a thickness of 6,000 or 7,000 feet, and then the Chemung fauna is sparse and confined to the lower strata. This red shale and sandstone

type is called the "Catskill group" in New York, the "Cadent series" of the Pennsylvania nomenclature. In the eastern Appalachian area this same lithological type of rocks continues all the way upward to the coal measures; green and red shales, sandstones and conglomerates, and occasionally thin beds of limestone, but with no trace of the marine faunas which characterize the interval in Ohio, Indiana, and, particularly, in the interior continental area. In Pennsylvania these rocks have been called "Vespertine Series," "Umbral Series," and "Seral Conglomerates" by the first survey, and "Pocono Sandstone and Conglomerate," "Mauch Chunck Red shale," and "Pottsville Conglomerate," by the second survey, and in central and eastern Pennsylvania they together reach a maximum thickness of nearly 5,000 feet. These peculiarities, however, do not extend westward of Pennsylvania and New York. Before reaching that line, in fact, the red shales have nearly disappeared from the total section, and as the Chemung fauna disappears upward, the new Waverly fauna comes in, but only in the border regions between the two areas, are found sections in which both the Chemung and the higher Waverly faunas appear. This Waverly fauna is a transitional fauna and is, in the east, generally associated with the higher Sub-carboniferous marine faunas, and in sections in which the next lower fauna is that of the Hamilton or Middle Devonian. In the Eureka faunas described by Mr. Walcott, representatives of it are found in the upper Devonian shales ("White Pine Shales") associated with traces of the upper Devonian faunas of the east.

The Central Continental Area.

The central continental area is typically represented in Iowa, Illinois and Missouri, and reaches into Indiana, Kentucky and Tennessee, and possibly far north into British America.

Its prevailing characteristics are calcareous shales and limestones, with some arenaceous admixture at the eastern and southern extremities, terminating in black shales, and rarely exceeding two or three hundred feet in thickness. On the north, east and south-east borders of the area the black shale termination is a conspicuous feature, but in the more central portion, in Iowa and Missouri, the black shale is either entirely wanting or but slightly represented.

In Illinois and Indiana the black shale reaches a thickness of one hundred feet or more, and is immediately followed by the shales and limestone of the Kinderhook, or Knobstone group holding a fauna closely allied with that of the Waverly group of Ohio. East of the Cincinnati axis the black shales are first thin; they thicken on going eastward, and distinctly represent the upper Devonian of Western New York. Including all that

is now rated as above the Hamilton shales and below the Bedford shales this upper Devonian of Eastern Ohio is from 400 to 2,000 feet in thickness, thinning westward (See Professor Orton's Preliminary Report on Petroleum and Gas, 1887, p. 26).

When we reach the central part of the interior area we find the Devonian represented by limestones running up into fine argillaceous shales, resting on upper Silurian limestones which in numerous places are of Niagara age and, in the southern border of the region, are more or less siliceous, and hold fossils of the later Silurian time, as in the *Delthyris shales* of Missouri which are, doubtless, as late as Lower Helderberg time. This central area lacks the black shale and runs up immediately into Sub-carboniferous limestones, calcareous shales and sandstones, and the total representatives of the Devonian are scarcely 200 feet thick.

The Western Devonian Area.

I take the Nevada section of the Eureka district as typical, since this has been carefully developed by the labors of Hague and Walcott. (See Walcott's Monograph, Paleontology of the Eureka district, U. S. Geol. Survey, 1884).

The peculiarities of this section are as follows:

Lying unconformably upon a thick series of limestone beds, representing the Trenton and, at the top, the Niagara of eastern sections, comes the *Nevada Limestone*, 6,000 feet thick, indistinctly bedded and siliceous below, and becoming massive toward the top with intercalated beds of shale and quartzite. The same fauna runs from bottom to top, but with some change in part of the species. In the lower 500 feet the fauna is distinctly lower Devonian, and in the terminal 500 feet it is as distinctly allied with the upper Devonian of the east. Throughout there are found species which in the typical eastern sections are restricted to particular zones. In its species it shows closer relationship with the Iowa Devonian than with the more eastern faunas, containing two species (see p. 265) that have been found far to the north in the Mackenzie River Basin, i. e. *Orthis McFarlini* and *Rhynchonella castanea*, (N. 67° 15′ long. 126° W.) Overlying this limestone is the White Pine Shale, a black shale, estimated at 2,000 feet in thickness, running into red and brownish sandstones and arenaceous shales, with some plant remains and a sparse fragmentary fauna which closely resembles in general character the fauna of the similar upper Devonian black shales of the eastern continental area.

In these western sections there is a remarkable difference in the range and habit of species. "Some species," as Mr. C. D. Walcott has shown, "have reversed their relative position in the group as they have been known heretofore, and others have a

greater vertical range." (Pal. of the Eureka District p. 4). Some cases mentioned by Mr. Walcott are *Orthis Tulliensis* at the top, *Orthis impressa* at the base, and several Corniferous corals at the upper horizon (see pp. 4 and 5, etc).

It is also noticed that the faunas in the higher shales show combinations of Devonian and Carboniferous types (White Pine Shales), but a careful study of the species reveals the characteristic changes of the general fauna that are seen in the eastern sections.

For instance, the new type of Brachiopods belonging to the genus *Productus* (called *Productella* in the New York Reports) begins in this western section with certain small forms typical of the lower and middle Devonian of the east, and it is only in the upper horizons that the larger Chemung types of *Productus* appear. The same thing is seen in the changes in the types of *Spirifera;* the characteristic upper Devonian *Sp. disjuncta* appears only in the upper part of the section as in the east. The peculiarities of this western section in its Paleontology, are most readily explained by the assumption, supported also by other facts, that throughout the whole age the deposits of this area were made in a wide, open ocean, with islands, perhaps, but with no great masses of land to disturb the general uniformity of the conditions of life.

The central area was, doubtless, at considerable distance from land but in no great depth of depression. The eastern continental area from Michigan around through Canada, New York and down the Appalachians, must have been during the Devonian age, near enough to shores for the faunas, as well as the nature of the deposits, to be affected by the ocean currents, and to feel strongly the effects of relatively small amounts of change of level between land and water. Here the faunas are both more local and more limited in geologic range, changing more suddenly and fully in their combinations and species. The conditions of the eastern border were those of rough and tempestuous coasts.

Conclusions.

There are thus, 1st, a northeastern border area, mainly composed of coarse, arenaceous deposits, thick, and with little to distinguish it into subordinate zones.

2d. An eastern continental area, with sandstones, limestones, shales and conglomerates alternating with each other, and presenting a rich and varied series of faunas, marking a considerable number of distinct zones which follow in a constant order.

3d. A central continental area, mainly limestone and soft argillo-calcareous shales, and, compared with the more eastern sections, very thin, and presenting a fauna which represents the

whole eastern Devonian and is plainly a sequent to an underlying upper Silurian fauna. It is followed by a Carboniferous fauna to which it is generically closely related, and about its border is terminated by a black shale.

4th. A western area represented by a massive thick series of limestones followed by black shales, not separated into distinct faunas, but carrying a common fauna showing but slight change from bottom to top.

With all these great contrasts in lithological, stratigraphical and paleontological characters the evidence is satisfactory that the several sections are representatives of the same geological age; that, taken as wholes, they do not represent parts, the one taking the place of an interval in the other, but they cover approximately the same interval, and probably represent approximately the depositions of the same length of geological time.

They are bound together, and their relationship certified to by the fossils they contain. The relationship is recognized in the combination of species to form faunas and in the varietal modification of species, as well as in the identity of the species themselves. We cannot find stronger contrasts across the Atlantic eastward than are found across the continent westward. The principles which the American geologist is required to apply in discussing the geology of his own domain are no less broad than those which the International Congress meets with when it attempts to unify nomenclature for all the world. Wherever unification is practicable in America it is practicable for all the world, and where America finds unification a cumberance it is useless for an International Congress to attempt it.

What is there in the Devonian system, as represented in North America, which demands uniformity of nomenclature, and wherein will attempts at uniformity in nomenclature either strain or misrepresent the facts?

1st. It is perfectly clear to a paleontologist studying the faunas and floras, that the system under consideration, in each of the so dissimilar types, is the representative of the Devonian system of Great Britain, Belgium, Germany and Russia, in all the central features of its marine and brackish invertebrate, and vertebrate faunas, and in its floras. That the name Devonian, as the first name used, should be applied to this system of rocks, we see no reason for dispute.

2d. In all the sections, in so far as they exhibit it, the order of sequence in the modification of faunas is the same, and this sequence as presented in foreign sections is found to follow the same order, wherever species are identical, or are closely allied varieties of the same type; their place of dominance in

the series is the same for each section, but the range may vary; in one area species may be restricted in range; in another, species may range through a long series of deposits. In other words, species which are found to have a world-wide distribution, although in one area they may be restricted to a particular stage of the Devonian, are likely to have a long geological range in other areas, not less than from bottom to top of some complete Devonian sections. But a particular combination of species, forming a characteristic fauna of a special stage in one area, occurs at the same relative position in any other area in which it appears. Such faunas are, however, actually more or less local, and, as far as the Devonian is concerned, it is not practicable to form more than three subdivisions of the Devonian to which to apply universally a uniform name. These three, in their general typical faunas, can be recognized (so far as they are present) in the different areas of America and Europe, the lower, typically seen in the Corniferous limestone of New York; the middle, represented in the Hamilton of New York; the upper, represented in the Chemung fauna of New York.

Any attempt to unify in the finer details is useless for America, and, of course, would be useless if attempted for all countries.

3d. In the sections of America alone there is found nothing in lithological composition or sequence which is uniform for the several areas.

In seeking uniformity of nomenclature the study of the American Devonian leads to the following conclusions:

(1) That uniformity is desirable in the names and prominent distinctive biological characters of the so-called systems.

(2) That valuable results may be reached by a discussion, on the part of those acquainted with the same system in the different parts of the world, as to the best biological criteria for marking the boundaries of the systems.

(3) That while uniformity is possible in subdividing a system into parts, the number of such parts, and the characters distinguishing them, must be determined after a wide, comprehensive and minute study of their biological characters.

(4) That preliminary work in classifying rocks should not seek uniformity, but should adopt local nomenclature, and that nomenclature based upon an exhaustive comparison of representative sections can alone reach a uniformity that will be of permanent value.

Art. V.—*On the law of Double Refraction in Iceland Spar;* by Charles S. Hastings.

The law of double refraction in uniaxial crystals, first discovered by Huyghens, was supposed for a time to be definitively established by Fresnel's deriving it from principles of molecular mechanics. It was soon recognized, however, that a fundamental hypothesis in his reasoning does not bear critical inspection; namely, that the elastic forces brought into play by distortions due to the passage of waves are the same in kind as those produced by the displacement of a single particle. In short, Fresnel assumed that the velocity of a light wave is independent of the direction of propagation and depends only upon the direction of vibration. There have been many notable efforts to get rid of this difficulty in the theory of double refraction by a general treatment. Cauchy, Mac Cullagh, Neumann and Green are those whose names are most closely connected with the interesting history of investigation in this field of mathematical physics. All of these investigations have the feature in common, that the natural interpretation of the equations makes the direction of vibration in plane polarized light lie in the plane of polarization. To adapt the solutions to the contrary assumption, which is almost certainly the only one which can be reconciled to the known phenomena of optics, requires the most artificial restrictions in the relations of the constants involved. By such forced interpretations of formulas having a large number of constants, it is possible to derive a law for double refraction, even in Iceland spar, which does not differ from Huyghens's construction by an amount discoverable by observation; but an agreement between observation and theory extorted in this way cannot be regarded as satisfactory.

Intimately bound up with this question of double refraction is the question as to whether the differing velocities of light in vacuum and in a dense medium are due to differing densities or differing rigidities. Of these two views, equally probable *à priori*, only the first can possibly be brought into agreement with the observed phenomena of reflection. But in the case of a velocity of propagation dependent on the direction of wave-motion, which is the case of double refracting media, the difficulty is to conceive of a *density* as dependent upon direction. Rankine made the ingenious suggestion that this difficulty might be avoided by assuming that the molecules of a crystalline solid move in a frictionless fluid, and thus that their effective masses might depend upon the direction of motion. The special interest of this view from our

standpoint is that it led Stokes to the first careful investigation of the accuracy of Huyghens's construction.*

In these investigations Professor Stokes found that the error in the construction could hardly exceed a unit in the fourth place of decimals, which was quite sufficient to disprove Rankine's hypothesis. This study, the details of which have not been published, remains unexcelled to the present time; for the investigations since made by Abria, Glazebrook and Kohlrausch, whether by the prism method or by total reflection, do not present a closer accordance between theory and observation. The results of earlier observers, cited in most treatises on double refraction, are all of quite inferior accuracy.

Of all these investigations, Glazebrook's, given in the Trans. Roy. Soc., vol. clxxi, 1880, is the most extensive. His method was to measure the deviations produced by four different prisms, so cut from the same piece of Iceland spar that the directions of the propagation of the light varied from an angle of $-3°$ to $+94°$ to the crystalline axis, the relation of this axis for each prism to its faces being determined by reference to planes of cleavage. The observations were made with considerable accuracy, indicating a probable error in the deduced indices of refraction considerably less than fifty units in the sixth place of decimals. The reductions, however, show a systematic deviation from Huyghens's construction, varying from 100 to 200 in the sixth decimal in the three hydrogen lines observed—the wave-surface for the more refrangible ray deviating most widely. This result would be of great theoretical interest if the values derived from observation were not vitiated by an important oversight in the details of the experiment, which the author himself points out. In view of this source of error the conclusion from the investigation is, that Huyghens's construction is true within the limit of error of these observations

Briefly, then, the state of the case is this. The law of double refraction in Iceland spar as given by Huyghens is known to be true to within about one part in ten thousand, but no reason, dependent on the theories of elasticity, can be assigned why it should be as accurate as this, or how much more accurate we may expect to find it. The labor of testing the law to the last degree of refinement possible with modern instrumental means seems well worth while; for, except its simplicity, there is no reason in the world why it should not break down just at the limit assigned by Stokes's observations. I am quite willing to admit, also, that the systematic deviations of Glazebrook's observations, so near the limit of magnitude set

* Proceedings of the Royal Society, June, 1872; quoted by Sir Wm. Thomson in his Baltimore Lectures, p. 273.

by Stokes, and so difficult to explain by any plausible hypothesis as to their cause, suggested a not too remote probability that they indicated a physical reality.

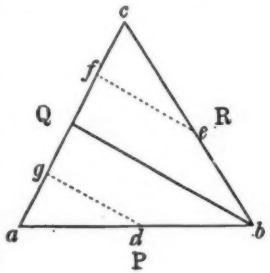
With these ends in view, all methods except those based upon prismatic refraction were practically excluded. Again, since it is impossible to get cleavage faces which admit of very accurate determinations of their angles of inclination, e. g., to within a second of arc, it seemed necessary to arrange the experiment so as to be independent of such accurate determinations. The method chosen, then, was to measure the various angles involved in an equilateral prism of Iceland spar in which one face was normal to the crystalline axis, the other two as nearly equally inclined to the axis as possible, and all three refracting edges as perfectly at right angles to the axis as practicable. Such a prism restricts the range of wave velocities which can be observed, but on the other hand, it enables us to find the direction of the crystalline axis from the observations themselves by mere considerations of symmetry, wholly independently of all assumptions of the law of double refraction.

(2) *Description of Prism.*

Since the accuracy of a determination of a refractive index depends largely on the character of the prism used, and especially in this case of extraordinary refraction, it may be worth while to describe the method employed to secure satisfactory results.

After selecting a good block of spar, a wooden model of the largest prism of desired orientation which could be obtained from the block was made. As this model represented the cleavage faces as well as the prism faces, it served as a guide as to how far any process of grinding should be carried. One of the obtuse trihedral angles was ground down, so that when the block rested upon this ground surface under a fixed telescope nearly perpendicular to it, the images of a distant object reflected by the three opposite cleavage faces could be brought to the crosswires of the telescope by merely rotating the block on the ground surface. This admitted of securing a face, P in the accompanying figure, very nearly perpendicular to the crystalline axis. The limit of accuracy was restricted only by the character of the reflection from the cleavage faces. The size of the face was determined by reference to the model. The next step was the formation of the surface, $dbefg$ of the figure, to serve as a base for the prism and a rough guide for the other two faces of the prism. It was ground perpendicular to P, and, by a process similar to that used in fixing the direction of P, equally inclined to the cleavage planes abQ

and $b\,c\,Q$. Then R was ground so that it made equal angles with the cleavage surfaces $a\,b\,Q$ and $a\,d\,g$, and an angle of 60° with P. As it was desirable to make this last angle tolerably accurate in order to eliminate all errors of the circle in a determination of the refracting angle, or, in other words, so that a repetition of the angle three times would bring the circle back to the same position within the range of the reading microscopes, the surface P was polished sufficiently to yield a good reflection, and then the angle at b was adjusted until it was equal to that of a glass prism known to be accurately 60°. Q was determined in a precisely similar way. The three surfaces were then polished to as close approximations to planes as possible. In this process most interesting differences in the physical properties of the surfaces were found, as might have been expected. R worked almost as readily as glass, except that its departure from flatness tended toward cylindrical surfaces instead of spherical. It was not difficult to make P flat, but the slightest carelessness in handling would produce tetrahedral pits in it. The surface Q, being inclined only 15° to the direction of cleavage, gave by far the most trouble, because it did not seem possible to get it very smooth by grinding. After carrying this process to its limit of accuracy, determined more, perhaps, by the extraordinary thermal properties of the material, than by purely technical difficulties in working, the faces were cut away until only circular areas were left on the three prism faces. These round faces were then modified, by methods which would only have an interest for the practical optician, until they were optically flat; that is, until their departures from their average planes was not more than a tenth of a wavelength of light. The test of flatness was the colors produced when white light was reflected nearly normally from the surface brought closely in contact with a surface of glass known to be plane. The diameters of the surfaces, in order of lettering, were:



2·8 cm., 2·8 cm. and 2.6 cm.

(3) *Spectrometer.*

The instrument with which the measures of the various angles were made has some features peculiar to it. The circle is of glass, 8 inches in diameter, and divided to single degrees, except in the case of the first degree, and three others separated

from it and each other by quadrants, which are subdivided to tenths of a degree. The observing telescope may be moved independently or clamped to the circle; it is checked in its rotation only by the collimating telescope. It is obvious that by this construction it is always possible to measure an angle so that one end of the arc shall be at a degree mark and the other end fall within a subdivided degree; hence both ends of the arc are within the range of the reading microscopes. The great and manifest advantage of this construction is that every angle can be accurately measured after determining the absolute place of only 396 lines or 198 diameters.

The reading microscopes have micrometer screws of 80 threads to the inch, with heads divided into 100 parts, one revolution of the screw being equal to one minute of arc. The magnifying power is 220 diameters, doubtless unnecessarily high, but not found inconvenient, and a much lower power would have necessitated a notable change in the design, either finer micrometer screws or longer microscopes with correspondingly higher table and telescope carrier. The probable error of a single setting of the microscope was found to be less than $0''{\cdot}3$, or less than half a division of the micrometer head.

The errors of the circle were determined by means of two auxiliary microscopes clamped to the base-plate of the instrument at opposite sides. By bisections and trisections the absolute position was determined of each diameter at multiples of 5° from the initial diameter, to within a probable error of less than $1''$. As practically every such interval was involved in the observations several times, equations of condition were formed as checks upon the results; if a discrepancy as great as $1''$ was found the intervals were re-measured. A determination of any angle was thus reduced to a maximum of five repetitions, whence the true angle could be found, and, incidentally, the corrections of four other arcs. As an illustration of the precision of the method, I may state that in the only case where a suspicion of the accepted value led to a complete redetermination of all the constants involved, the correction deduced differed only $0''{\cdot}1$ from the former one. The origin of the suspicion was afterwards found to be a false temperature correction. This determination of the errors of the circle was the most laborious part of the whole investigation.

(4) *Angles of prism.*

The angles measured were those between the normals to the faces P and Q, Q and R, R and P, which were made with all attainable accuracy; those between the normal to P, and the normals to its three adjacent cleavage faces; the normal angle

between R and the narrow cleavage face at b; and finally, the normal angles between the cleavage faces $a\,b\,Q$ and $b\,c\,Q$ respectively. The precision of all the measures involving reflection from a surface of cleavage is of course much inferior to those made upon the polished surfaces. The first group gives the refracting angles, and the others only serve to determine the direction of the crystalline axis, a datum not used in the final reduction but useful as a check on the work.

The general method of determining these angles was as follows: The telescope replaced the fixed collimator which was removed. By means of a plate of plane parallel glass and a *quasi* collimating eyepiece* the axis of the telescope was rendered strictly perpendicular to the axis of rotation of the instrument. The focal adjustment of the telescope could be made at the same time with great precision: magnifying power used, twenty diameters. Following this adjustment the glass plate was replaced by the prism, which was so adjusted that the line of collimation fell close to the center of each face when in position for observation. That this condition, a most important one, was fulfilled, was determined by removing the ocular and looking at the prism through the telescope tube.

TABLE I.—*Angles of prism* $= a = 60$.

PQ			PR			QR		
Obs.	t	Red.	Obs.	t	Red.	Obs.	t	Red.
+1′·205	17·2	+1′·285	−2′·516	17·0	−2′·519	+1′·330	16·5	+1′·303
·242	17·1	·280	·492	17·0	·519	·298	16·5	·303
·273	17·0	·276	·521	17·0	·519	·254	16·6	·293
·407	19·8	·421	·521	19·55	·394	·067	19·2	·046
·421	20·0	·412	[·652]	19·65	----	1·141	19·25	·041
·432	20·0	·412	·418	19·75	·384	0·908	19·55	1·013
·391	20·0	·412	·350	20·7	·338	·895	21·0	0·875
·469	20·1	·417	·315	21·0	·323	·883	21·0	·875
·453	20·0	·412	·225	21·5	·299	·858	21·5	·828
·390	20 0	·412	·235	21·3	·308	·836	21·1	·866
475	20·1	·417	·350	21·1	·318	·842	21·1	·866
·514	20·1	·417	·354	21·1	·318	·873	21·2	·856
·470	21·0	·457	·306	21·2	·313	741	22·5	·732
·484	21·2	·466	·231	20·8	·333	·703	22·6	·723
·481	21·1	·462	·242	22·9	·230	+0·695	22·8	+0·704
·453	21·7	·489	·247	23·0	·225			
·427	21·7	·489	−2 ·247	23·0	−2 ·225			
·478	21·6	·485						
·519	21·6	·485						
·445	21·6	·485						
·435	21·8	·494						
·511	23·0	·548						
·511	23·0	·548						
+1 ·528	23·0	+1 ·548						

* This is described in the paper "On the influence of temperature on the optical constants of glass." This Jour., III, vol. xv, p. 271.

In the case of the prism angles each was repeated three times, whence, since they were all quite close to 60°, not only were all errors of graduation eliminated, but the absolute values of the instrumental arcs 120° and 240° determined with great accuracy. The influence of temperature on the magnitudes of the angles becomes evident even in comparatively rude observations. Table I gives *all* the measures of these angles. Of course the angles given are the supplements of those directly observed; they are also corrected for circle errors. Following the column containing the observed angle is given the temperature of the prism, and then the value reduced to a temperature of 20° C. The method by which the last column was calculated will be given farther on.

The observation of PR enclosed in brackets is rejected. Two or three others might have been rejected without changing the results except to give them smaller probable errors.

In order to find the values of the angles a standard temperature (20° C.) was chosen as the standard, observation equations of the form

$$M = m + n\,(t-20),$$

whence normal equations of the form

$$\Sigma\alpha^2 .\, m + \Sigma\alpha\beta .\, n - \Sigma\alpha .\, M = 0,$$
$$\Sigma\alpha\beta .\, m + \Sigma\beta^2 .\, n - \Sigma\beta .\, M = 0,$$

gave the means of finding m and n. The values of the coefficients of the normal equations are as follows:

	$\Sigma\alpha^2$	$\Sigma\alpha\beta$	$\Sigma\beta^2$	$\Sigma\alpha M$	$\Sigma\beta . M$
PQ	24	13·7	72·67	34·514	22·647
PR	16	7·9	64·6	−37·570	−15·588
QR	15	2·4	66·42	14·324	− 3·980

The observed values of α from these equations are:

For PQ	60° 1′. 412 ± 0′·006	+ 0′·0454 $(t-20°)$
PR	59 57′. 628 ± 0′·009	+ 0′·0489 $(t-20°)$
QR	60 0′. 970 ± 0′·008	− 0′·0950 $(t-20°)$

The probable errors of a single observation of an angle were found to be 0′·028, 0′·035 and 0′·032, respectively, and the probable errors of the coefficients of the terms containing the temperature 0′·0035, 0′·0045 and 0′·0039, respectively. The probable error of 2″ for a single observation seems large, considering the refinement of the method used, and indeed it would be for a glass prism; but regarding the enormous change from temperature and the extreme difficulty of determining that of the prism, it must, I think, be regarded as satisfactory.

These constants derived directly from observation are subject to certain geometrical conditions which will modify them very slightly and reduce the probable errors. As it was

found, in the course of the observations, that the normal to any one face is inclined only 12″ to the plane fixed by the other two normals, we have—

$$\Sigma\alpha = 180°$$
$$n_1 + n_2 = -n_3.$$

But as observed,

$$\Sigma\alpha = 180° \; 0'{\cdot}010 \pm 0'{\cdot}013.$$
$$n_1 + n_2 = -n_3 + 0'{\cdot}0007 \pm 0'{\cdot}006.$$

Adjusting the observed values in accordance with the equations of condition we have finally:

$$\alpha_{PQ} = 60° \; 1' \; 24''{\cdot}59 \pm 0''{\cdot}29.$$
$$\alpha_{PR} = 59° \; 57' \; 37''{\cdot}42 \pm 0''{\cdot}43.$$
$$\alpha_{QR} = 60° \; 0' \; 57''{\cdot}98 \pm 0''{\cdot}39.$$

$$n_3 = -5''{\cdot}68 \pm 0''{\cdot}19.$$

The value of n_3 enables us to find at once the difference in the principal coefficients of thermal expansion, as well as the variations of the angles of the rhombohedron. By an obvious relation, if a_1 and a_2 are the coefficients in the axial direction and at right angles to it respectively, we deduce

$$a_1 - a_2 = 10^{-6}(31{\cdot} \pm 1{\cdot}).$$

The best value known is that of Fizeau, which is

$$10^{-6}(31{\cdot}6).$$

But the relations of immediate value to us are those of the temperature variations of the angles between the normals of P and an adjacent cleavage face, of R and the cleavage face b, and of the two faces $a\,b\,Q$ and $b\,c\,Q$. They are, in the order named, if ϑ is the measured angle

$$\frac{\Delta\vartheta}{\Delta t} = +0'{\cdot}056.$$
$$= -0'{\cdot}103.$$
$$= -0'{\cdot}085.$$

(5) *Position of crystalline axis.*

The measures upon which this constant depends are subject to large errors on account of the imperfect reflections from the cleavage faces, especially from the edge b, which is only 1^{mm} wide and gives two images. The values given below are reduced to a temperature of 20° C.

Angle.	
Pb	$= 44° \; 39'{\cdot}12 \pm 0{\cdot}50.$
P(abQ)	$= 44° \; 36'{\cdot}57 \pm 0{\cdot}045.$
P(ady)	$= 44° \; 37'{\cdot}05 \pm 0{\cdot}120.$
Rb	$= 75° \; 25'{\cdot}00 \pm 0{\cdot}160.$
(abQ) (bcQ)	$= 105° \; 4'{\cdot}88.$

Of these the first and fourth, giving them equal weights, yield

$$Pb = 44° 38'·26$$

which, with the second and third, give

$$44° 37'·29$$

as the angle between the crystalline axis and the normal to a cleavage plane. The last of the measured angles implies

$$44° 36'·70$$

for the angle between the axis and the normal to a cleavage face. This value, however, rests upon two observations only and cannot therefore be regarded as of great weight. We may, perhaps, attribute to it a weight $\frac{1}{3}$ that of the value derived from the other measures, whence the accepted value becomes

$$44° 37'·19.$$

This value gives, for the direction of the axis drawn from *P inward*, an inclination

$$\xi = 1' 4''·1$$

from the normal to P towards Q, and

$$\eta = 0' 12'',$$

i. e., 12″ below the refracting plane of the prism QR; they can hardly be in error as much as 15″.

It is perhaps worth noting that the accepted value 44° 37′·19 gives 105° 5′·07 for the dihedral obtuse angle of the rhombohedron at 20° C., which is practically the value accepted by mineralogists.

(6) *Angles of deviation.*

Minimum angles of deviation were determined in each case; there are thus two angles for each prism-angle. The line pointed upon was the more refrangible component of the D line of the solar spectrum, except in the case of the extraordinary image by the faces Q R, of which the dispersion was too small to admit of easy separation, and, by mistake, in four pointings on the double deviations for the ordinary image by the same refracting angle when D_1 was observed on one side. Care was taken to adjust the collimator, telescope and prism, so that the axial ray passed through the center of the prism in both positions for minimum deviation, i. e., right and left. The lines of collimation were made at right angles to the axis of the circle and to the refracting faces by means of the plane glass plate and the collimating eyepiece. For observing the spectrum a magnifying power of 31 was employed. Table

II contains all the measures for the ordinary ray, then the temperature (t), the barometric height (Bar.), and the angle corrected to 30 inches barometric height. In the table, the mistakes mentioned, and which were confined to the four preceding the last, are corrected by adding 0′·285, the measured distance between D_1 and D_2.

TABLE II.—*Double angles of deviation for ordinary ray D_2.*

$2\Delta_0 = 104°$

PQ				PR				QR			
Obs.	t	Bar.	Cor.	Obs.	t	Bar.	Cor.	Obs.	t	Bar.	Cor.
+8′·454	20·3	29·85	+8′·423	−3′·772	19·4	30·1	−3′·752	+7 ·658	16·7	30·1	+7′·678
·472	20·4	29·85	·441	·701	19·8	30·1	·681	·546	17·1	30·1	·566
·497	20·7	29·85	·466	·661	19·9	30·1	·641	·531	17·2	30·1	·551
				·559	20·3	30·1	·539	·336	17·9	30·1	·356
				·560	20·2	30·1	·540	·134	18 8	30·1	·154
				·552	20·6	30·1	·532	+7′·085	19·0	30·1	·105
				·618	19·8	29·75	·669	+6′·983	19·1	30·1	+7′·003
				·479	20·3	29·75	·530	·921	19·7	30·1	+6′·941
				−3′·455	20·4	29·75	−3′·506	·914	20·1	30·1	·934
								·799	20·1	30·1	·819
								·839	20·2	30·1	·859
								·743	20·6	30·1	·700
								+6′·680	20·6	30·1	+6′·762

The observations for PR and QR were reduced by forming observation equations of the type

$$M = m + n(t - 20).$$

and, the temperature correction for PQ being assumed as the same as that for PR, the reduced values for Δ are, for

PQ	52°	4′	$10''\cdot20 \pm 0''\cdot54 + 6''\cdot72(t-20)$
PR	51°	58′	$11''\cdot52 \pm 0''\cdot18 + 6\cdot72(t-20)$
QR	52°	3′	$26''\cdot10 \pm 0''\cdot30 - 7''\cdot17(t-20)$

TABLE III.

$2\Delta_e =$

PQ 94°				PR 94°				QR 72°			
Obs.	t	Bar.	Cor.	Obs.	t	Bar.	Cor.	Obs.	t	Bar.	Cor.
+7′·983	20·7	29·85	+7′·955	−2′·518	19·6	30·1	−2′·537	+3′·474	16·8	30·1	+3′·489
8′·045	20·7	29·85	8′·017	·555	19·7	30·1	·574	·454	16·9	30·1	·469
·101	20·8	29·85	·073	·454	19·9	30·1	·472	·456	17·4	30·1	·471
·110	20·9	29·85	·082	·430	19·9	30·1	·448	·360	17·7	30·1	·375
+8′·088	21·0	29·85	+8′·060	·436	20·5	30·1	·454	·356	18·9	30·1	·371
				·391	20·6	30·1	·409	·307	19·0	30·1	·322
				·429	20·0	29·75	·475	·331	19·2	30·1	·346
				−2′·361	20·1	29·75	−2′·407	·309	19·4	30·1	·324
								[3′·495]	20·1	30·1	----
								·294	20·4	30·1	·309
								·277	20·5	30·1	·392
								·251	20·6	30·1	+3′·266
								[3′·634]	20·6	30·1	----

Table III gives the double angles of deviation as measured for the extraordinary ray for each refracting angle. As has already been stated, the deviation is that belonging to D_2, except in the case of the edge QR, where, on account of the small dispersion, the sodium line was set upon as a single line.

As before, the observations enclosed in brackets are rejected. These were reduced in quite the same way as were the deviations for the ordinary ray, with the following resulting values for Δ_ϵ:

PQ	47°	3′	$58''\cdot23\pm0''\cdot39+3''\cdot60(t-20°)$
PR	46°	58′	$45''\cdot69\pm0''\cdot24+3''\cdot60(t-20°)$
QR	36°	1′	$39''\cdot21\pm0''\cdot21-1''\cdot58(t-20°)$

In order to reduce the angle of deviation for QR to what it should be for D_2, the angular distance between D_1 and D_2 for the ordinary ray was determined, and half its product by $\frac{d\Delta_\epsilon}{d\Delta_o}$ for this region of the spectrum, was taken as an additive correction. The value of the correction was found to be $3''\cdot85$, whence the deviation for the extraordinary ray D_2 for QR becomes

$$36° \quad 1′ \quad 43''\cdot06\pm0''\cdot21$$

(7) *Principal indices of refraction.*

The crystalline axis has been found to make an angle of less than 1′ with the plane bisecting the refracting angle QR; hence we may apply the ordinary formula connecting the index of refraction with the angles of minimum deviation and refraction, namely,

$$\mu=\frac{\sin\frac{\Delta+\alpha}{2}}{\sin\frac{\alpha}{2}}.$$

The resulting indices will be the principal indices for calcite at a temperature of 20° C.

	$\mu_o=$
for PQ	$1\cdot658393\pm2$
PR	$1\cdot658387\pm2$
QR	$1\cdot658387\pm2$
	$1\cdot658389\pm1\cdot2$

The single value of μ_ϵ is

$$1\cdot486450\pm1\cdot4$$

(8) *Test of Huyghens's Law.*

We are now in a position to test the law of extraordinary refraction from the principal indices of refraction and the

observed extraordinary deviations by the refracting angles PQ and PR. First, we have the well known law,

$$\left[\frac{1}{\mu'_\varepsilon}\right]^2 = \frac{\cos^2\vartheta}{\mu^2_o} + \frac{\sin^2\vartheta}{\mu^2_\varepsilon},$$

where μ_o and μ_ε are the reciprocals of the principal wave velocities as before, and μ'_ε is the reciprocal of the velocity of the extraordinary wave whose normal makes an angle ϑ with the crystalline axis. This enables us to compute μ'_ε, knowing ϑ. Second, we have the series of relations given by Professor Stokes (British Association Report, 1862),

$$\mu'_\varepsilon = \frac{\sin\varphi}{\sin\varphi'} = \frac{\sin\psi}{\sin\psi'}$$
$$\varphi + \psi = \Delta + \alpha$$
$$\varphi' + \psi' = \alpha$$
$$\operatorname{tg}\frac{\varphi' - \psi'}{2} = \operatorname{tg}\frac{\alpha}{2}.\operatorname{tg}\frac{\varphi - \psi}{2}.\cot\frac{\Delta + \alpha}{2},$$

where φ ψ are the angles of incidence and emergence respectively, and φ' ψ' the angles which the wave normal makes with the faces of the prism within it. These relations enable us to derive a value for μ'_ε from the observations, perfectly independently of any assumption as to the law of double refraction if we know either φ or ψ. They afford a much readier test than that of calculating the deviations for an assumed law.

We do not, it is true, know the values of φ for the extraordinary refractions by PQ and PR, but as the prism was always set for minimum deviation it is easy to find these values, either by taking advantage of the fact that Huyghens's law is already known to be nearly true, whence the angle of incidence for minimum deviation can be calculated, or, more simply, from the relation

$$\frac{\sin\varphi}{\sin\varphi'} = \frac{\sin\psi}{\sin\psi'},$$

and the two purely geometrical equations which follow this equation above.

It is found by trial that for PQ, the light being incident on Q the value of φ which satisfies the condition is 50° 25′, and for PR and incidence on R, the value of φ is 50° 21′. A small change in these angles does not alter the difference between the observed and calculated values of μ'_ε, which affords the test of the law.

The substitution of these values in the equation of Stokes gives—

	μ'_ε
PQ	1·606114±1·6
PR	1·606103±1·6

It remains to calculate the values of μ'_ε from Huyghens's theory from the known values of φ' or ϕ' and the assumed direction of the crystalline axis defined by ξ above, since η is so small that it can be regarded as zero. The measured value of ξ is 1′ 4″ with a considerable uncertainty, but I find that a value of 1′ 6″ will make the differences between observation and theory symmetrical. With this value we have

	$\mathcal{S}$	μ'_ε [calc.]
PQ	31° 19′ 45″·68	1·606109±1·8
PR	31 19 58 ·34	1·606099±1·8

where the probable errors are calculated without disregarding the fact that we have imposed the arbitrary condition that the differences shall be symmetrical.

The difference between a measured index of refraction in Iceland spar at an angle of 30° with the crystalline axis, and the index calculated from Huyghens's law and the measured principal indices of refraction, thus appears to be 4·5 units in the sixth place decimals, while, assuming the truth of the law we ought to expect, from the probable errors of the quantities involved, a difference of ±2·4, only about half as great. There is, however, one source of constant error in the observations which has not been alluded to, namely, the fact that the temperatures of the prism were measured by a different thermometer in the case of the angles of the prism and the angles of deviation. In the former a rather insensitive thermometer divided to single degrees and estimated to tenths was used, and in the latter a very sensitive thermometer divided to half-degrees. By reference to my notes I find that the two systems of temperatures are connected only by an eye comparison on a single day, so, although I believe that the error of comparison cannot be much over one tenth of a degree, it is by no means certain, or even improbable, that an error of this magnitude may enter. It was not thought in that stage of the investigation that such an error was of any significance. Unfortunately one of the thermometers has since been broken so that a direct comparison is out of the question. The observations of the ordinary indices contain implicitly, however, the desired correction as appears from the following reasoning:—

Let dt be the excess of the reading of the first thermometer, used in the prism-angle measures, over that of the second; then its most probable value is that which renders the probable error of the mean value of μ_o a minimum, when the three observed values are regarded as independently determined magnitudes.

Thus $$\frac{d\mu_o}{dt}=\frac{d\mu_o}{d\alpha}\cdot\frac{d\alpha}{dt}=4\cdot2\times5\cdot68 \text{ for QR}$$
$$=-4\cdot2\times2\cdot84 \text{ for PQ and PR,}$$

the first differential coefficient being derived from the formula from which μ_o is calculated, and the second is given on p. 66. From these and the values of μ_o on p. 70 treated as independent determinations, we have

$$23\cdot9\,dt=-2$$
$$11\cdot9\,dt=\ \ 2$$
$$11\cdot9\,dt=-4,$$

whence

$$dt=-0°\cdot084\pm0\cdot032.$$

From this it is obvious that such a correction is required. Supposing, then, that the angles of the prism given above correspond to a temperature of 19°·916 C. instead of 20° C. we have the following definitive values for the quantities involved:

	α	Δ_o	Δ_ε	μ_o
PQ	60° 1′ 24″·83	52° 4′ 10″·20	47° 3′ 58″·26	1·658392
PR	59 57 37·66	51 58 11·52	46 58 45·69	1·658387
QR	60 0 57·60	52 3 26·10	36 1 43·06	1·658389

whence $\mu_o=1\cdot658389$ μ_ε 1·486452

	μ'_ε	μ'_ε [calc.]
PQ	1·606113	1·606110
PR	1·606102	1·606100.

The conclusion is, that Huyghens's law is probably true to less than one part in five hundred thousand, and, consequently, that there is no known method by which we can hope to discover an error in it by observation alone.

New Haven, Nov., 1887.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Decomposition of the Hydrides of the Halogens by Light in presence of Oxygen.*—Some time ago it was observed by Backelandt and by McLeod that hydrogen chloride gas, when exposed to the combined action of atmospheric oxygen and sunlight, was partially decomposed, chlorine being evolved. In order to determine the conditions under which this change is effected, Richardson has made a series of experiments on hydrogen chloride, bromide and iodide gases, (1) when the gaseous mixture exposed to the sunlight is moist; and (2) when it is dry.

In the former case, oxygen was present (a) in only sufficient quantity to oxidize the hydrogen, or (b) in large excess. Bulbs of about 300 c. c. capacity were filled with the gaseous mixture and sealed. The hydrogen chloride gas was prepared from sodium chloride by the action of pure sulphuric acid. The oxygen was freed from any chlorine it might contain by passing it through sodium hydrate. After exposure to the light, the bulbs were opened under water and the chlorine compounds thus absorbed. The resulting solution, made up to known volume, was divided into two equal parts. In the first the total chlorine was determined and in the second the free chlorine. In the first experiment the moist gases were mixed in the ratio of 4 vols. hydrogen chloride and 1 vol. oxygen, and the bulb was exposed to sunlight for 24 days. The free chlorine formed amounted to 0·34 per cent. In the second experiment, in which the oxygen was 8 vols. to four of hydrogen chloride and in which the exposure was 21 days, 73·81 per cent of chlorine was evolved, the mixture in the bulb being distinctly greenish after five days. In the third and fourth experiments, the gases were mixed in the same proportion and exposed to sunlight for 57 days. Notable quantities of hypochlorous oxide or other oxide of chlorine were produced. In the fifth experiment the gases were both carefully dried over phosphoric oxide. After 27 days exposure in one case and 63 days in another, not a trace of free chlorine could be detected. The hydrogen chloride was then saturated with moisture and mixed with dry oxygen. But an exposure to sunlight of 60 days failed to produce any free chlorine. Hence, a mixture of hydrogen chloride and oxygen is perfectly stable in sunlight not only when dry, but even in presence of aqueous vapor, provided liquid water be absent. Similar experiments were then made with hydrogen bromide. When the gases were moist and the oxygen was that required to oxidize the hydrogen, an exposure of 46 days produced 0·64 per cent of free bromine. When, however, the oxygen was in large excess, 7·73 per cent of bromine was set free in the same time. In case the gases were dry, no bromine was evolved. In the experiments with hydrogen iodide, 94·31 per cent of free iodine was produced in 20 days when the oxygen was not in excess and 96·08 per cent when an excess of oxygen was used. Even dry mixtures of these gases were found to be decomposed by sunlight. Hence, the author concludes: 1st, The stability of the moist hydrides of chlorine, bromine and iodine is dependent on the mass of oxygen present, in excess of that required for their complete decomposition. 2d, Dry or partially dry hydrogen chloride and bromide are completely stable, even when mixed with a large excess of oxygen. 3d, Dry hydrogen iodide is decomposed in presence of oxygen.—*J. Chem. Soc.*, li, 801–806, November, 1887. G. F. B.

2. *On the Influence of Liquid water in promoting the Decomposition of Hydrogen chloride by Sunlight in presence of Oxygen.*—In a paper immediately following the one above mentioned,

ARMSTRONG discusses the apparently anomalous result that water in the liquid state is necessary to the reaction just described. He regards the interaction in this case as only another instance showing the general fact that interactions which are commonly assumed to occur between *two* substances, are possible more frequently than not, only in presence of a third substance (which he calls a *catalyst*). The case in question is parallel to that of the oxidation of sulphur dioxide investigated by Dixon. "In gaseous mixtures chemical change appears so take place only when a comparatively high electro-motive force, or its equivalent, is employed; one sufficient to produce disruptive discharge being usually required. Regarding the interaction as a case of electrolysis, a gaseous mixture of HCl, O, and OH_2 therefore might be expected to prove insensitive to light. But an aqueous solution of hydrogen chloride is one of the best of liquid conductors and it is easy, therefore, to understand that a relatively small electromotive force should suffice to electrolyze a *liquid* system of the same three elements."—*J. Chem. Soc.*, li, 806–807. G. F. B.

3. *On the Concentration of Solutions by Gravity.*—Experiment teaches that a homogeneous solution left to itself at constant temperature, preserves sensibly its homogeneity. GOUY and CHAPERON have examined this question mathematically in order to see how far this result, taking gravity into the account, is in accordance with thermodynamic principles. And they find that under these conditions, the permanent state of a solution is not one of absolute homogeneity but that the density of the liquid increases from the surface downward according to a determinate law; so that in time the primitive homogeneity of a solution will be destroyed by gravity, and a new state of equilibrium will be established within it. To show that the principle of Carnot is in contradiction with the hypothesis of absolute homogeneity in the case of a heavy solution in the permanent state, the authors suppose a perfectly homogeneous solution placed in a vessel of height H. Let a very small portion of this liquid of volume V, at its upper surface, be supposed temporarily isolated from the remainder of the solution. If the weight $d\omega$ of the solvent pass by distillation from this isolated portion to the rest of the liquid at constant temperature, evidently no work will be expended. Suppose now that, since the weight of the solvent $d\omega$ has gone from this isolated portion to the rest of the liquid, the density of this portion increases in consequence by an amount dD, its volume will diminish by dV; and now if by reason of this increased density, this portion sinks to the bottom of the vessel, it will do a positive amount of work equal to H (V$-d$V) dD. If after this we suppose the homogeneity of the solution to be re-established by diffusion the cycle will be closed, the total work done in the cycle will be zero and hence dD must be zero. It is not possible therefore for a solution to be perfectly homogeneous in the permanent state unless its density does not vary for an infinitely small variation of the concentration. But if, on the contrary, the solution is not homogeneous,

its density increasing gradually downward, the isolated portion above mentioned will be in equilibrium in the liquid when it has fallen through a distance dH; so that the positive work done in this case will be an infinitesimal of the second order and therefore negligible. From a formula deduced in the paper, the authors have calculated the amount of substance at the top and at the bottom of a column 100 meters high, for four different solutions. For cadmium iodide at top 0·166, at bottom 0·153; a difference of 0·013. For sodium nitrate 0·20 and 0·196; a difference of 0·004. For common salt 0·11 and 0·1095; a difference of 0·0005. And for sugar 0·55 and 0·546; a difference of 0·004. These differences, though apparently too small to have any practical value, have a very considerable theoretical importance.—*Ann. Chim. Phys.*, VI, xii, 384, Nov., 1887. G. F. B.

4. *On the Percentage of Oxygen in the Air.*—HEMPEL has published the results of analyses of the air of Dresden, made for the most part by his assistants Oettel and Schumann, in comparison with analyses of air collected simultaneously at Poppelsdorf, near Bonn, by Kreusler, at Cleveland by Morley, at Para, Brazil (lat. 1½° S.) by Pusinelli, and at Tromsöe, Norway (lat. 69½° N.) by Schneider. The samples analysed were taken daily between April 1 and May 16, 1886, the hour being 2:12 P. M. at Bonn, and the corresponding time at the other stations. The results are given in detail in tabulated form. They show that the mean percentage of oxygen in the air was for Para 20·92, Bonn 20·92, Cleveland 20·93, Dresden 20·93, and Tromsöe 20·95. The highest observed percentage was 21·00 at Tromsöe on April 22d; and the lowest 20·86 at Para on April 26th. The mean percentage as deduced from all the experiments is 20·93.—*Ber. Berl. Chem. Ges.*, xx, 1864, June, 1887; *J. Chem. Soc.*, lii, 885, Oct., 1887.

G. F. B.

5. *On the Constitution of Selenous Acid.*—MICHAELIS and LANDMANN have continued their researches on the constitution of selenous acid and have offered new proof that this is a di-hydroxyl-acid $SeO.(HO)_2$. They have produced the chloride of ethoxyselenyl, $C_2H_5O.SeO.Cl$, by distilling selenyl chloride with absolute alcohol for a long time with an inverted condenser. They have also formed di-ethyl selenite $(C_2H_5O)_2SeO$, either by the action of selenyl chloride upon sodium ethylate or by that of silver selenite on ethyl iodide. This ether has a density of 1·49 at 16·5° and boils between 183° and 185°.—*Ber. Berl. Chem. Ges.*, xx, (Ref.) 625, Nov., 1887. G. F. B.

6. *Indexing of Chemical Literature.*—The fifth annual report of the Committee of the American Association for the Advancement of Science on Indexing Chemical Literature has recently been received. The report mentions the publication of Professor C. E. Munroe's Index to the Literature of Explosives, Part I, in which no less than 442 volumes of serials have been indexed. After noticing reports of progress from eight persons, the report considers the suggestion of the chairman made at the Buffalo meeting as to the

formation of a Standard List of Abbreviations of titles of Chemical Periodicals. The committee give the nine principles by which they were governed in compiling the Provisional List of Abbreviations which accompanies the report. This list gives proposed standard abbreviations of 206 chemical periodicals (including some of general science) for adoption by chemists with a view to securing uniformity. Those desiring copies of this list can obtain them by addressing the chairman of the committee, care of the Smithsonian Institution.

The report also gives a list of the Indexes to chemical literature published to date, twenty in number. The committee is now constituted as follows: H. Carrington Bolton, Chairman, F. W. Clarke, Albert R. Leeds, Alexis A. Julien, John W. Langley, Samuel H. Scudder, and C. K. Wead.

7. *Mechanical Equivalent of Heat.*—Dr. DIETERICI employing the electrical method for the determination of the mechanical equivalent of heat, obtains as the results of his series of measurements, 424·4 and 424·2. The highest and lowest values differ very little from the mean of the determinations. The value of the specific heat of water taken was the mean of the determinations between 0° C. and 100° C. The author believes that the specific heat of water can best be determined by the electrical measurement of the mechanical equivalent of heat.—*Nature*, Nov. 10, 1887, p. 48. J. T.

8. *Radiation in absolute measure.*—Mr. J. T. BOTTOMLEY placed a wire in a blackened copper cylinder which was exhausted of air. The wire was heated by an electric current and the amount of energy measured which was necessary to maintain the wire at a constant temperature. The constant temperature was shown by the constancy of the resistance of the wire. The energy was measured by obtaining the value of the current and the difference of potential. The measurements were obtained at such a low pressure that a further reduction of this pressure did not appreciably affect the energy given off. By means of an asymptotic curve the energy given off by radiation was then calculated.

The energy radiated, expressed in gram-water Centigrade units, was at 408°, $378{\cdot}8 \times 10^{-4}$; at 505°, $726{\cdot}1 \times 10^{-4}$. Two equal wires of platinum were enclosed by melting in two equal cylinders. One of these wires was covered with lamp black. By a suitable arrangement both wires were raised from a red to a white heat by known electrical currents and known differences of potential. It was seen that the temperature of a dull body must be much higher than that of a polished one in order to exhibit the same brightness.—*Proc. Roy. Soc. Lond.*, xlii, pp. 357–359, 1887; ibid., pp. 433–437. J. T.

9. *Maximum of Light Intensity in the Solar Spectrum.*—G. MENGARINI after a careful study concludes that the relative brightness of different colors of the spectrum changes, and the maximum of the intensity of light is not in any fixed position. It varies between tolerably wide limits.—*Rend. della R. Acc. dei Lincei* (4) iii, pp. 482–489, 1887. J. T.

10. *Relation of the wave-length of light to its intensity.*—One of the most important questions in optics is the question whether the velocity of light depends upon its intensity. EBERT has undertaken an elaborate study of this point. Interference fringes were employed, the writer showing that changes in wave-lengths amounting to only $\frac{1}{200,000}$ of their values, or changes in velocity of light amounting to $\pm 1{\cdot}5$ kilometers can be detected by this method. Different sources of light were employed. It was found that the wave-lengths and the velocity of light did not change a millionth in value when the intensity of light varied from 1 to 250.—*Ann. der Physik und Chemie*, No. 11, 1887, pp. 337–383.

J. T.

11. *Brief notice of a paper by Mr. Hallock* entitled: The Flow of solids, etc.;* by W. SPRING. (Communicated by the author.)—I have shown, it will be remembered, by numerous experiments, that solid bodies possess, to different degrees, the property of being welded together, while cold, under a sufficiently strong pressure. In compressing bodies of a different chemical nature I have been able to obtain, at a low temperature, a number of combinations of bodies in a solid state, combinations which are, generally, produced only with the aid of a temperature more or less high. These researches were undertaken with the view of deciding whether it is possible to find in bodies in a solid state, any trace of the peculiarities which especially characterize the liquid state.

I have also been led to state, as the result of my experiments, since 1880, that "*matter assumes, under pressure, a condition relative to the volume it is obliged to occupy;*" but this condensation is permanent only when the matter admits of different allotropic states. Since then, new experiments,† still in part unpublished, have made me recognize the importance of the part that a certain degree of temperature plays in these phenomena, so that for the solid state, as well as for the gaseous one, *a critical temperature* would be remarked, above or below which, the changes by simple pressure would be no longer possible.

The consequences of all this is, for instance, that liquid bodies must pass under pressure into a solid state, taking of course the critical temperature, into account, if their specific volume is smaller in a solid state than in a liquid one, and conversely. This *converse* has been demonstrated first by Mouzon, since then by myself in coöperation with my friend J. H. van't Hoff. I had intended verifying also the first proposition, but I have been anticipated, to my great satisfaction, by M. Amagat‡ who has just produced the solidification of several liquids by the action of pressure. The verification of the general result of my experiments has given me great pleasure; its value will escape no one.

This taken for granted, I come to Mr. Hallock's article. The author imputes to me the absurd idea that solid bodies

* See this Journal, xxxiv, No. 202, October, 1887, p. 277.

† Zeitschrift f. phys. Chemie, i, p. 227. ‡ Comptes Rendus, cv, p. 165, 1887.

would all *liquefy* under the action of pressure. He even imagines that I have drawn this conclusion from my own experiments! To second his statement he alters some passages of my works, substituting for the word "*welding*" (*souder*) while I have used that of "*fusion*," or even in misconstruing the text. The reader may judge: Mr. Hallock makes me state, for instance (p. 281), "Sulphur prismatic—5000 atm.-fusion to the octahedral form . ." he adds, of his own invention: "and so on through a long and varied list." But I said, on page 391 of my memoir of 1880: "*Du soufre prismatique transparent, fraichement préparé, a été soumis à une pression de* 5000 *atm. à la temperature de* 13°; *il s'est* MOULÉ *en un bloc opaque beaucoup plus dur que ceux qu'on obtient par fusion.*"! . . . . . After having thus prepared the ground, he gives an account of some new experiments which have shown him, naturally, that solid bodies do not fuse under pressure! Finally, he closes by showing my absurdity, referring to Amagat's experiments which prove, as I have just called to mind, *the solidification of certain liquids by pressure*, that *which excludes the contrary.* It is quite evident that there is no reason for arguing with Mr. Hallock, since his study, which rests on a chimera, is, in my opinion, null and void. But I think I have a right to protest against the carelessness which has led him thus to misstate my views.

Liége, 6 Nov. 1887.

12. *Lessons in Elementary Practical Physics:* vol. ii, *Electricity and Magnetism;* by BALFOUR STEWART and W. W. HALDANE GEE. 497 pp. 12mo. London and New York, 1887 (Macmillan & Co.).—Those who are already familiar with the preceding part of this excellent work on Practical Physics will not need any special introduction to this second volume. It covers the subjects of electricity and magnetism, the first three chapters giving the elementary phenomena and principles to be worked through by the student experimentally; after this he is fitted to take up the more advanced portion dealing in successive chapters with the measurement of resistance, the tangent galvanometer, the determination of the magnetic elements, electro-magnetism, the condenser, electrometer and so on.

II. GEOLOGY AND NATURAL HISTORY.

1. *Communication by Raphael Pumpelly, of the U. S. Geological Survey, on the fossils of Littleton, New Hampshire.*—In the course of a reconnaissance of some of the limestone areas of New England made under my direction by Mr. T. Nelson Dale in August and September, 1885, the following fossils were found in the limestone and interbedded slates at Fitch Hill, the north end of Blueberry or Parker Mountain, near Littleton, N. H.

The determinations of the trilobites and mollusks were made by Mr. Chas. D. Walcott, those of the corals by Mr. C. Rominger. *Dalmanites limulurus* (Green), abundant; *Strophomena rhom-*

boidalis (Wahl.), *Pleurotomaria*, fragment, *Strophodonta*, a species allied to *Trematospira multistriata* (Hall), *Stromatopora*, *Syringopora* similar to Niagara forms, *Favosites* most likely *favosa* (Goldf.), *Favosites* with the special character of Niagara forms *Favosites*, a ramose species, Niagara group.

The following fossils were also found at the same locality, thus corroborating the discoveries made there in 1870 by Professor Ch. H. Hitchcock, and the determinations by the late Mr. Billings, (this Journal, III, vol. vii, 1874, pp. 468, 557; also Geology of New Hampshire, vol. i, p. 48, 1874, vol. ii, p. 339–340, 1877, *Pentamerus Knightii* (Low.), *Halysites*, differing but slightly from *H. catenulata* (Lin. sp.), *Zaphrentis*, crinoid columns, fragments of another gasteropod. The following species also given by Professor Ch. H. Hitchcock from the same locality were not found: *Favosites basaltica* (Goldf.), *Favosites Gothlandica* (Lam.) and a Lichas.

The fossils found by Professor Hitchcock seemed to indicate the age of the Upper or Lower Helderberg for these deposits, with a preponderance in favor of the latter. Mr. Walcott's and Mr. Rominger's determinations agree however in assigning the beds to the Niagara period.

2. *The Geological history of the Swiss Alps.*—Prof. RENEVIER, one of the ablest and most active of Swiss geologists, has an important paper on the Alps, in the "Archives des Sciences," of Geneva, for October 15, 1887 (xviii, 367). He first discusses the age of the crystalline rocks, and opposes the hypothesis of their universal Archæan age and igneous origin. He observes that the crystalline rocks are so varied, so frequently stratiform, not to say stratified, so similar, so indisputable sedimentary rocks, that their general igneous origin cannot, in his view, be sustained. Some may be of this nature, but the micaceous and other schists appear to be ancient argillaceous rocks, foliated by pressure; some gneisses, old sandstones more or less metamorphosed. Further, instead of uniform unconformability between the fossiliferous beds of the Coal formation and these alleged Archæan schists, in many places there is perfect concordance, and the beds of the Coal formation also are often semi-crystalline.

It appears, moreover, to be more and more incontestable that some of the crystalline rocks of the Alps contain organic remains. Some time since Sismonda reported the discovery of an impression of an Equisetum in a crystalline rock of the Val Pellina. Recently, M. A. Muller announced the discovery of Crinoids and other fossils, apparently Devonian, in a kind of Graywacke, from the Etzlithal; and M. Stapff has found, in schists from the interior of the St. Gothard tunnel, joints of Crinoids in calcareous mica schists, impressions of fucoids in shining slates, and in a calcareous bed intercalated with mica schists, a microscopic network (figured by him), which probably pertained to a sponge. The past year the discovery has been made known of two trunks which are cer-

tainly vegetable, in the sericitic (hydromica) schist of Guttanen. Such facts may leave some doubts still, but they afford, at least, a strong presumption that there is not the long unrepresented interval between the Archæan and Carboniferous which has been claimed by some; on the contrary, that the Silurian and Devonian may be represented in different parts of the Swiss as well as in the Austrian Alps.

Mr. Renevier continues with an account of the extensive distribution of the Carboniferous beds in the Swiss Alps; of the Triassic, but mostly the upper Trias, and, unlike the Austrian, without marine fossils; and of the Triassic and Jurassic, which in the Rhetian beds—here referred to the Lias rather than the Trias—include the first of the marine beds in this series. These marine beds are stated to indicate, apparently, that the sea encroached on the region of the Alps in a direction to the southeastward, the Rhetian beds not extending to the High Alps, the upper Lias reaching farther in that direction than the Rhetian, and the Upper Jura, or Malm, constituting the calcareous backbone of the mountains, being found between the different crystalline centers of the Alps, on both flanks of Mt. Blanc, in the valley of Chamouni on the north and that of Entrèves on the south; and also at Zermatt at the foot of Mt. Rosa. The fossils in the limestones of these high regions are not determinable, but the beds can be followed even along the metamorphic regions, to places where, as at Mœveran, the fauna is determinable. It hence appears that, at this Jurassic period, the sea had its largest extension, and the Alps were an archipelago, consisting of more or less oblong islands. After this there is evidence of a gradual retreat of the waters.

As the geological chart shows, the Cretaceous beds occupy only the outer zone of the northern Alps. The Lower Cretaceous beds have the greatest extension. Passing to the later epochs of the Cretaceous, the distribution shows a gradual retreat of the sea. The Lower Cenomanian beds of the Upper Cretaceous are the last and are only circumferential in distribution; after this the emergence of the Alps was carried on through the Cretaceous until it was complete.

The upward movement of the Cretaceous era probably continued through the era of the oldest Eocene (Paleocene, anterior to the Nummulitic beds), so that at this time the Swiss Alpine region was continental. After this a return of the sea commenced at each extremity of the Alps, producing the Nummutic deposits of Kressenberg, Bavaria, and of Appenzell and Schwytz which is prolonged even to Lake Thun; and also other beds in the southern part of Savoy; the intermediate region being still "terra firma," as proved by terrestrial and lacustrine deposits. The Nummulitic beds were followed by the Flysch—a marine deposit of the later Eocene; and after it, came a new retreat of the waters.

The Miocene beds occur in the Rigi, the Pèlerin and the Speer, but are not known to occur in the synclinal valleys of the Alps; they may yet be traced into some of them, but it appears certain that the Alps had become mainly emerged by the commencement of this era.

The Flysch, the last of the Eocene marine deposits, is much folded up with the beds below, entering into the remarkable double folds; and it is probable that the great flexures of the Swiss Alpine chain had hardly commenced before the era of its deposition had closed. The era of folding may have covered the whole of the Miocene period.

By the beginning of the Pliocene period, the folding was completed, and the Alps had acquired their present altitude or may have exceeded it.

The Glacial era probably began with the close of the Pliocene. Then followed an interglacial period, represented by immense accumulations of rounded, stratified gravel, which are situated between two systems of angular erratics; and during this epoch the plains of Switzerland became free of the glacier. Later, owing to new elevations or new meteorological conditions, the ice spread itself anew over the plains; but whether to a greater or less extent than in the first glacial epoch is uncertain. Then followed the era of the formation of the great accumulations of gravel in the Alpine valleys, and the terraced materials along the lake valleys, and river borders, and the final retreat of the ice to its present limits.

3. *Gradual variation in intensity of metamorphism.*—A paper on Crystalline and Metamorphic rocks of the lower Himalaya, Garhwal and Kumaum, by C. S. Middlemiss, B.A. (Records Geol. Surv. India, xx, part 3), gives some facts on this subject which show that the metamorphic phenomena of India are much like those of New England. The author emphasizes two points; that "the schist near the gneissose granite is entirely a thorough crystalline schist, a fact needing no miscroscope to demonstrate; and, secondly, along a line of country where rock is exposed at every step, it is seen that this culminating intense form *graduates* into a widespread less intense form, and this in turn, *graduates* into ordinary slates and quartzites." "About a mile from any outcrop of gneissose granite, as we approach the Dudatoli massif, in no matter what direction, there is a rapid, but gradual change in the metamorphism of the schistose beds. The faint films of micaceous material assume by degrees the aspect of distinct layers of mica-plates of considerable thickness." "Garnets gradually assemble in the schist; first showing as minute pin-heads under a coating of what one may call mica-leaf, and gradually increasing in size and definiteness concomitantly with the mica until they reach an average size of peas and rarely as large as filberts."

An exact counterpart as to the change in the mica and garnets with increasing intensity of metamorphism, connected with a graduation from hydromica schist into gneiss occurs within 10 miles

west of New Haven, Connecticut, and in a less restricted area, in the Taconic range of Massachusetts. At the India locality the gneiss graduates into porphyritic gneiss and granite; so, west of New Haven, the gneiss becomes a coarse porphyritic gneiss with crystals of orthoclase as large as the thumb; and at the junction of the mica schist and gneiss several alterations of the two occur, becoming coarser and coarser, before the passage is complete into the porphyritic gneiss. In the gneiss a mile west of the junction, large masses of porphyritic granite occur with the layers of the micaceous gneiss broken and involved in it; which has appeared to indicate that part of the rock material of the porphyritic gneiss had been reduced by the heat to a pasty condition, and in that state had been forced up through the fractured schist. J. D. D.

4. *Mission Scientifique du Cap Horn*, 1882–1883; par le Dr. Hyades. Published under the auspices of the "Ministères de la Marine et de l'Instruction Publique." Tome iv, *Geologie.* 242 pp., 4to, with 30 plates and 3 maps. Paris, 1887. (Gauthier-Villars.)—In this volume on the geology of the region about Cape Horn, after a brief notice of other explorations, the author describes the various rocks about Orange Bay and other lands in its vicinity, and gives fine figures of many microscopic sections on ten of the plates. The rocks are mainly crystalline, and include diorytes, andesytes, diabase, trachyte, hornblende schist, granulyte, quartzyte, quartz-syenyte, and others. Several of the plates give excellent views of columnar rocks and of the scenery of the rugged region, and the maps show well the wonderful Fuegian archipelago. An appendix contains descriptions of other specimens collected in 1882 by Professor Lovisato of the University at Cagliari, and among them, in the vicinity of Cape Conway, a limestone in schist and a marly slate each containing fossils, that of the limestone a coral near *Coscinocyathus calathus* Bornemann, a Silurian fossil.

Among the interesting facts cited from Darwin, in the introductory historical notes, is his discovery of Cretaceous fossils in an argillaceous schist or slate on the summit of Mount Tarn *Ancyloceras simplex* and a *Natica* and *Pentacrinus*, and near Port Famine specimens referred to *Hamites elatior*, *Lucina eccentrica*, and a Venus and Turbinolia.

The author refers also to Wilkes's "Narrative," and cites a few sentences. He makes no mention of the writer's report on the vicinity of Orange Harbor, in which is mentioned, besides other facts, the discovery on the shores to the north of the harbor, in a slate, where passing into argillaceous sandstone, of a species of *Belemnite.* It was February, 1839; an opportunity for only one day's excursion over the region was allowed. Accompanied by one of the sailors of the vessel, the walk was continued for some hours over the bleak hills, and then along the sea-shore with the intention of returning by the shore to the harbor where the vessels of the expedition were at anchor; and on this coast part of the excursion, about half way between the harbor and the head of

the bay (the latter probably Point St. Bernard on the map of the work here noticed) the fossils were found "quite thickly distributed" in one of the layers, "15 to 20 occurring in a slab a foot square" (p. 604). The coast had many deep coves and long points, so that the one excursion was prolonged unintentionally, and somewhat imprudently considering the savage climate and people of the region, to twenty-four hours, the best place under some bushes being selected for the night. But no more fossils were found.

The other volumes of the series are: I, History of the Voyage; II, Meteorology; III, Terrestrial Magnetism, and Constitution of the Atmosphere; V, Botany; VI, Zoology; VII, Anthropology and Ethnography. Only II, III and IV are published. J. D. D.

5. *The American Geologist.*—The prospectus of an American geological monthly has been recently issued, announcing the appearance of the first number on the first of January. Its aim will be to cover all branches of the science in its publication of papers and notices of discoveries, and also to afford special aid, by suggestion and information, to the teacher in geology. The editors and publishers for the coming year are as follows: Professor S. Calvin of Iowa, Professor E. W. Claypole, of Ohio, Dr. Persifor Frazer of Philadelphia, Professor L. E. Hicks of Nebraska, Mr. E. O. Ulrich of Kentucky, Dr. A. Winchell of Michigan and Professor N. H. Winchell of Minneapolis. The Journal will be published at Minneapolis, in monthly numbers of at least fifty-six octavo pages each, at three dollars a year. There is no lack of good material from home investigation for the American Geologist. It promises to be of great service to the science and the country.

6. *Geology and Mining Industry of Leadville, Colorado;* by S. F. Emmons. 750 pp. 4to, with a folio Atlas and numerous plates.—United States Geological Survey, Clarence King, Director. Washington, 1886.—This report of Mr. Emmons gives a full account of the Leadville region, as regards its geology, its mineral veins and their products, its mines and its mining industry, and discusses ably the origin or genesis of the veins of ore. The illustrations accompanying the text represent scenery, the microscopic structure of the rocks, furnaces, implements for assaying and smelting, and various other matters connected with the mining operations. The Atlas contains maps with contour lines of Central Colorado and of the Leadville mining region, and others giving in color the topographical geology, besides numerous geological sections. The work is grandly prepared in all respects and is a very important contribution to geology and the science of mines and mining.

7. *Fifteenth Annual Report on the Geological and Natural History Survey of Minnesota for the year,* 1886. N. H. Winchell, State geologist. 496 pp. 8vo. St. Paul, 1887.—This volume consists chiefly of Reports by Dr. Alexander Winchell on observations in northeastern Minnesota, which is accompanied

by a map and fifty-seven structural illustrations; Prof. N. H. WINCHELL, on the iron ore of Minnesota; and by AUG. E. FOERSTE, notes on four species of Illæni. Besides the valuable notes and discussions connected with the iron ores, there is a large amount of facts bearing on the relations of granite and the associated schistose rocks, (gneiss and mica and hydromica schist), which go far in the way of elucidating the conditions of origin of granite and the associated schists. The accompanying figures are highly instructive. There is much in the report which geologists will find it profitable to study.

8. *New York Paleontology: Vol. VI, Corals and Bryozoa, containing descriptions and figures of species from the Lower Helderberg, Upper Helderberg and Hamilton Groups;* by JAMES HALL, State Geologist and Paleontologist, assisted by GEORGE B. SIMPSON. 298 pp. 8vo, with sixty-seven lithographic plates. Prof. Hall has here added another to the long series of volumes on the Paleontology of New York. The number of species described is 371, and of these 328 are figured on the plates. Prof. Hall states, in his prefatory remarks, that about 100 additional species he has studied and had drawn, which he could not add to the present volume on account of the restriction limiting its extent. The illustrations of the species are beautiful, and the volume a great contribution to paleozoic paleontology and especially to the department of Bryozoans.

9. *Annual Report of the Geological Survey of Pennsylvania, for* 1886, *by the State Geologist.* 574 pp. 8vo.—This volume, Part 1 of the report, treats of the Pittsburgh Coal Region, and has been prepared as regards the geological structure, by E. V. d'Invilliers; the general mining methods of the Pittsburgh Coal Region, by Selwyn Taylor; the mining methods practised by Westmoreland Coal Co., Irwin, Pa., by A. N. Humphreys, Engineer; and the character and distribution of Pennsylvania plants, by L. Lesquereux. The subjects of the other parts yet to be issued, are: II, Oil and Gas region; III, Anthracite Coal region; IV, Miscellaneous Reports. A large colored geological map of Southwest Pennsylvania, with special reference to the Pittsburgh Coal bed, accompanies the report.

10. *Fossil Mammals from the White River formation contained in the Museum of Comparative Zoology.* Bull. Mus. Comp. Zool., xiii, No. 5, 1887.—Messrs. W. B. SCOTT and H. F. OSBORN here present an abstract of a detailed memoir in course of preparation. Besides a number of species first described by Dr. Leidy, there are here included notices of the new species *Hyænodon leptocephalus* Scott, *Hyotherium americanum, Menodus tichoceras, M. dolichoceras, M. platyceras,* and a restoration of *M. Proutii* (*Titanotherium*) on plate II; *Metamynodon planifrons, Hyracodon major, H. planiceps.* Plate I gives a restoration of *Hoplophoneus* (*Drepanodon*) *primævus* Leidy, one-fourth the natural size. Many wood-cuts also illustrate the paper.

11. *Diatomaceous Earth in Nebraska.*—In a soft, chalky rock of Tertiary age near Scotia, Greeley County, Nebraska, there are numerous diatoms. I have seen entire specimens, or well characterized fragments, of the following species: *Navicula cuspidata, Cocconema lanceolatum, Amphipleura sigmoidea, Pinnularia radiosa, Nitzschia longissima, Nitzschia sigmoidea.* Mr. F. W. Russell, who kindly furnished me a specimen of the rock, reports that the stratum is twenty feet in thickness near the base of a cliff seventy-five feet high on the North Loup river. The diatoms form but a small proportion of the whole mass of rock. L. E. H.

University of Nebraska, Oct. 6th, 1887.

12. *The Upper Beaches and Deltas of the Glacial Lake Agassiz;* by Warren Upham. 8vo. 1887. Bull. U. S. Geol. Survey, No. 39.—An important paper by Mr. Upham, who has studied more than any other geologist the Winnipeg Lake region with reference to its ancient drainage. The memoir is accompanied by a map of part of Dakota, Minnesota and Manitoba.

13. *Supposed diamonds in a Meteorite.*—It is stated (*Nature* of Dec. 1) that a meteoric stone, which fell at Krasnoslobodsk, in Russia, on September 4, 1886, has yielded a number of small granules having the hardness, density and other characters of the diamond and believed to be that mineral. It is interesting to note in this connection, the cubic form of graphitic carbon called cliftonite, from the meteoric iron of Youngdegin, by Fletcher, and which he suggested might perhaps be pseudomorphous after diamond (this Journal, Sept., 1887).

14. *Cryptolite.*—Mallard has shown recently that the rare cerium phosphate, cryptolite, occurring in minute crystals embedded in apatite from Norway, has the form of monazite and is doubtless to be referred to that species.

15. *Grundriss der Edelsteinkunde von* Dr. P. Groth. 165 pp. 8vo, with a colored plate. Leipzig, 1887 (Wm. Engelmann).—Professor Groth has found time, among his more serious duties, to prepare this attractive little volume on the properties of the gems. His experience as a writer and teacher has enabled him to present the subject more systematically and intelligibly, than has hitherto been done.

16. *Rivista di Mineralogia e Cristallografia Italiana, diretta* da R. Panebianco, vol. i, 81 pp., with 3 plates. Padua, 1887.—The latest addition to mineralogical publications is this Italian review which, judging from the first volume is of much more than local interest. Among its contents may be mentioned well illustrated papers on celestite, zircon, and datolite.

17. *Catalogue of all recorded Meteorites,* with a description of the specimens in the Harvard College collection including the cabinet of the late J. Lawrence Smith, by Oliver Whipple Huntington, Ph.D. From the Proceedings of the American Academy of Arts and Sciences, vol. xxiii, pp. 37–110, with five plates.—Since the acquisition of the cabinet of Dr. Smith, the Harvard collection of meteorites has taken a prominent place

among the great collections of the world, and this fact makes the catalogue, carefully prepared and annotated by Dr. Huntington, of great and general interest.

18. *A Chapter in the History of Meteorites*, by the late WALTER FLIGHT. 223 pp. 8vo, with seven plates. London, 1887 (Dulau & Co.).—This volume is for the most part a republication of papers by Dr. Flight, giving a digest of a large number of memoirs on meteorites since 1868. It is thus a continuation of the works of Buchner and Rammelsberg, and to the student of the subject and to the collector it is of high value. It is to be hoped that it may be widely distributed not only for the sake of making its author better known who was so early arrested in his active scientific life, but also because the proceeds are to go to increase the amount of the *Flight Fund*, which is being raised for the benefit of his family.

19. *Das pflanzenphysiologische Praktikum;* by Professor DETMER of Jena. Jena, 1888, 8vo, pp. 352.—Vegetable Physiology takes its appliances for research from Chemistry and Physics. Many of the special methods of using these appliances with the least expenditure of time and labor, and with the greatest certainty of securing trustworthy results, were brought together in a useful handbook long since out of print, namely Sachs' Experimental-Physiologie der Pflanzen. Since the date of that work, 1865, many new methods have been introduced, and new fields of investigation have been opened. It seems, therefore, quite time that some compendious and yet convenient treatise should be available to teachers and students, in which modern methods of experimental research in this interesting department should be clearly described.

By the lectures by Sachs and by Pfeffer, and by the small treatise by Bretfeld, a student is placed in possession of references to the memoirs giving details of researches in the different parts of the subject, but there does not appear to be any single handbook for laboratory practice which covers the ground of the present work. The subject is divided into the two parts, (1) Nutrition, (2) Growth and Movements. As might be naturally expected the author has given some description of what he regards the most desirable single method for investigating each minor point, but in many instances the methods are merely described without critical examination of their merits or faults. Perhaps this, on the whole, is all the better for any student who might be led thereby to distrust a method until he had for himself examined rival methods not here referred to, but it would be all the worse for any student who should confine himself to the single methods here detailed. The latter course would inevitably lead to superficiality. But in the hands of a judicious teacher the treatise can be made of great assistance.

One of the charms of Strasburger's "Practicum," consists in the almost colloquial minuteness with which all possible difficulties are explained, to the student of histology; the present trea-

tise lacks that charm. Many a student who uses it will be likely to lose his interest in experimenting, when he finds that some trifling direction has been omitted by which success could have been secured. No handbook dealing with manipulation should fail to give even fussy details, rather than leave the student to find out all such minor points of practice for himself.

Although we miss a good many excellent methods which should find place in a work of this sort, it is nevertheless a valuable aid in the laboratory. The illustrations are numerous and excellent. It is to be regretted that the work has no index. G. L. G.

III. Miscellaneous Scientific Intelligence.

1. *Proceedings of the Colorado Scientific Society*, vol. ii, part 2, 1886, 153 pp. 8vo. Denver, Col. (published by the Society).—The Colorado Society, though somewhat removed from the chief scientific centers has shown an admirable spirit in the amount and excellence of the scientific work it has called out. This closing part of volume ii contains a series of papers chiefly geological and mineralogical. Mr. P. H. Van Diest describes the telluride veins of Bowlder county, with an excellent map. A paper by Charles G. Slack follows on the artesian wells of Denver; these wells number about 200, furnishing about 3,000,000 gallons daily, they draw their water from sandstone or shale layers, from a few inches to 80 feet in thickness, at varying depths down to 900 feet. Mr. S. F. Emmons furnishes notes on some Colorado ore deposits. Mr. W. Cross on the Cimarron land-slide of July, 1886; Mr. R. C. Hills on the circulation of water through the strata of the Upper Cretaceous Coal-measures of Gunnison county. There are also a number of mineralogical articles, several of which have been printed in this Journal.

2. *Relative Proportions of the Steam Engine*, being a rational and practical discussion of the dimensions of every detail of the steam engine, by W. D. Marks, 3d edition, revised and enlarged. 295 pp. 8vo. Philadelphia, 1887 (J. B. Lippincott Company).—A new and considerably enlarged edition of this excellent manual will be acceptable to all interested in the steam engine. The chief additions are in an important line, being an attempt on the part of the author, approaching the subject both from the mathematical and practical side, to develop the laws of the condensation of steam within the steam cylinder.

3. *Modern American Methods of Copper Smelting;* by Edw. D. Peters. 342 pp., large 8vo. New York, 1887. (Scientific Publishing Company.)—The author gives here a practical and detailed description of the methods employed in this country for smelting copper, adding more than usual of minute directions and with many useful data as to the actual cost. The volume will be valuable to the student and still more to the practical worker.

OBITUARY.

Ferdinand Vandeveer Hayden.—Dr. Hayden, for many years at the head of Government Exploring Expeditions in the Rocky Mountain region, and the author of various geological papers, died on the 22d of December, in his 59th year. A notice of his special scientific work is necessarily deferred.

APPENDIX.

ART. VI.—*Notice of a New Genus of Sauropoda and other new Dinosaurs from the Potomac Formation*; by O. C. MARSH.

THE variegated red and gray clays which form so conspicuous a feature in their outcroppings between Baltimore and Washington have long been a puzzle to geologists. They have been supposed to be Mesozoic, but as no characteristic fossils had been found at the typical localities, or in the known extensions of the deposits, their true age was uncertain. They are evidently above the red Triassic sandstones, and are supposed to pass into clays which extend beneath the Cretaceous marls of New Jersey.

The United States Geological Survey has named these problematic deposits the Potomac formation, and the Director recently requested the writer to institute a special search for vertebrate fossils, to solve, if possible, the question of its age. The field work was intrusted by the writer to Mr. J. B. Hatcher, whose experience in the West has especially fitted him for it. The results of two months' investigation prove that these deposits, so long supposed to be nearly or quite destitute of fossils, contain a rich vertebrate fauna, apparently of Upper Jurassic age, but quite distinct from any hitherto discovered in this country.

The most abundant fossils obtained are remains of Dinosaurian reptiles, three orders of which are represented, and in the present article, some of the new forms are described. Associated with these are remains of crocodiles and tortoises, also of Jurassic types, some fishes, and a few mollusks. A number of plants have been found, mainly conifers and cycads. The strata containing these fossils are evidently of lacustrine origin.

Pleurocœlus nanus, gen. et sp. nov.

The most common fossils secured thus far from the Potomac formation are the remains of a small Dinosaur which clearly belongs to the *Sauropoda*, but is by far the most diminutive member of this group yet discovered. Portions of the skull, vertebræ, and limb bones of several individuals have been obtained, and these agree so nearly that they may be referred to one species. They differ somewhat in size, owing apparently to a difference in age.

In comparing these remains with the *Sauropoda* now known, they appear to resemble most nearly those of the genus *Morosaurus*, so well represented in the upper Jurassic of the Rocky Mountain region. A careful comparison, however, shows that they belong to a distinct genus. The teeth are of the same general type as those of *Morosaurus*, but their crowns are mainly compressed cones, and not spoon-shaped. The dentary bone is slender, and rounded at the symphysis, instead of having the massive, deep extremity seen in *Morosaurus*. The maxillary is also lighter, and less robust. The supra-occipital agrees closely in shape with that of *Morosaurus*, and forms the upper border of the foramen magnum, as in that genus.

FIG. 1. FIG. 2.

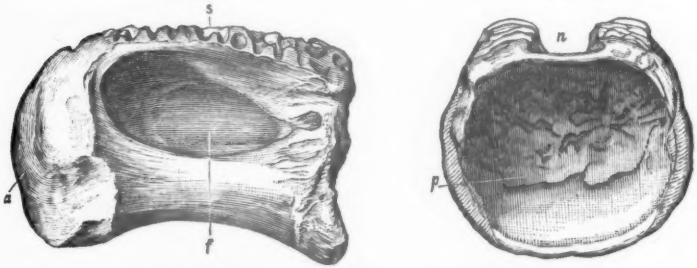


FIGURE 1. Dorsal vertebra of *Pleurocœlus nanus*, Marsh; side view.
FIGURE 2. The same vertebra; posterior view.
Both figures are one-half natural size.

The cervical and dorsal vertebræ are elongate, and strongly opisthocœlous. The latter are much longer than the corres-

ponding vertebræ of *Morosaurus*, and have a very long, deep cavity in each side of the centrum, to which the proposed generic name refers. All the trunk vertebræ hitherto found are proportionately nearly double the length of the corresponding centra of *Morosaurus*, and the lateral cavity is still more elongate. These points are shown in the posterior dorsal vertebra represented in figures 1 and 2. The neural arch in this region is lightened by cavities, and is connected with that of the adjoining vertebræ by the diplosphenal articulation.

The sacral vertebræ in *Pleurocœlus* are solid, as in *Morosaurus*, but much more elongate. The surface for the rib, or process which abuts against the ilium, is well in front, more so than in any of the known *Sauropoda*. Behind this articular surface, is a deep pit, which somewhat lightens the centrum. These characters are seen in the sacral vertebra represented in figures 3 and 4.

FIG. 3.

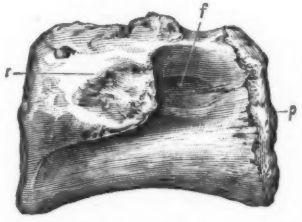


FIG. 4.

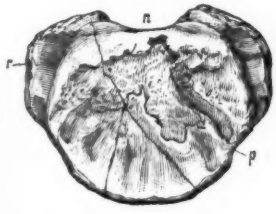


FIGURE 3. Sacral vertebra of *Pleurocœlus nanus*, Marsh; side view.
FIGURE 4. The same vertebra; posterior view.
Both figures are one-half natural size.

The first caudal vertebra has the centrum very short, and its two articular faces nearly flat, instead of having the anterior surface deeply concave, as in the other known *Sauropoda*. The neural spines in this region are compressed transversely. The middle and distal caudals are comparatively short, and the former have the neural arch on the front half of the centrum, as shown in figures 5 and 6.

FIG. 5.

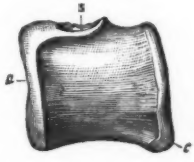


FIG. 6.

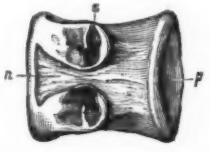


FIGURE 5. Caudal vertebra of *Pleurocœlus nanus*, Marsh; side view.
FIGURE 6. The same vertebra; superior view.
Both figures are one-half natural size.

The bones of the limbs and feet preserved, agree in general with those of the smaller species of *Morosaurus*, but indicate an animal of slighter and more graceful build. The metapodials are much more slender, and the phalanges are less robust than in the other members of the order.

The known remains of the present species, representing several individuals, indicate an animal not more than twelve or fifteen feet in length, and, hence, the smallest of the *Sauropoda*. They were found at several localities of the Potomac formation in Prince George Co., Maryland.

Regarding the present species as typical, some of the more special characters distinguishing these remains from the known *Sauropoda* are as follows:

(1) Teeth with compressed, or flattened crowns.

(2) Dorsal vertebræ with low neural sutures, and elongate excavation in each side of centrum.

(3) Sacral vertebræ solid, with cavity in each side, and with face for rib in front.

(4) Anterior caudals with flat articular faces, and transversely compressed neural spines.

(5) Middle caudal vertebræ with neural arch on front half of centrum.

These characters appear to indicate a distinct family, that may be called the *Pleurocœlidæ*.

Pleurocœlus altus, sp. nov.

A larger species apparently of the above genus is represented by various remains from the same localities as the specimens just described. A tibia and other limb bones show the animal to have had elongated posterior extremities, at least a third longer proportionately, than in *Morosaurus*, which these remains, in other respects, clearly resemble.

The tibia has the proximal end compressed transversely, with its outline sub-rhomboidal. The cnemial crest is well developed. The shaft is solid throughout, with the exception of a very small cavity near the middle, and here it is sub-ovate in transverse section. The distal end is much flattened anteroposteriorly, and the notch in the articular face, characteristic of the *Sauropoda*, is well marked. This tibia is twenty-five inches (M. ·635) in length, with its proximal end seven inches (M. ·177) in fore and aft diameter, and the distal end six inches (M. ·152) in transverse diameter. Both extremities are rugose, indicating a heavy covering of cartilage. The fibula is massive, and its distal end somewhat expanded. The astragalus was free, and is wanting in the present specimen.

Priconodon crassus, gen. et sp. nov.

The existence of another herbivorous Dinosaur in the same horizon of the Potomac formation is indicated by a number of fragmentary remains, the most characteristic of which is the tooth figured below. This may be regarded as the type specimen. Although resembling somewhat the teeth of *Diracondon* from the Jurassic of the West, it is quite distinct. It has the narrow neck, swollen base, and flattened crown of that genus, but the serrated edges meet above at a sharp angle, instead of forming a wide curve at the apex.

FIG. 7. FIG. 8. FIG. 9.

FIGURE 7. Tooth of *Priconodon crassus*, Marsh; side view.
FIGURE 8. The same tooth; end view.
FIGURE 9. The same; inside view.
All the figures are twice natural size.

The surface shown in figure 7 is much worn by the opposing tooth. In figure 9, the pit formed by the succeeding tooth is seen near the top of the fang.

The other remains at present referred to this species were not found with this tooth, and hence, their relations to it are uncertain. They will be described more fully elsewhere.

All the remains supposed to pertain to this animal are from the Potomac formation, Prince George Co., Maryland.

Allosaurus me[illegible], sp. nov.

Besides the herbivorous Dinosaurs described above, remains of two carnivorous forms were secured from the same horizon. The larger of these, which may be provisionally referred to the genus *Allosaurus*, is represented by various specimens, the most characteristic of which are teeth, and bones of the limbs and feet. The teeth are remarkably flat and trenchant, with the edges finely serrated, and the surfaces very smooth. The limb bones, and even the phalanges, are unusually hollow, and the latter have the articulations finely finished. The principal dimensions of some of the parts preserved are as follows:

One tooth has the crown 30^{mm} in height; its antero-posterior diameter at base 15^{mm}; and its transverse diameter 7^{mm}.

The astragalus is 55^{mm} in width; and 50^{mm} in fore and aft diameter.

A first phalanx of the hind foot is 90^{mm} in length.

These specimens would indicate an animal ten or twelve feet in length.

These remains are from the same horizon and localities as those above described.

Cœlurus gracilis, sp. nov.

The smallest Dinosaur found in these deposits is a very diminitive carnivore, apparently belonging to the genus *Cœlurus*. It was not more than one-half the size of the western species, and its proportions were extremely slender. The bones are very light and hollow, the metapodials being much elongated, and their walls extremely thin. An ungual phalanx of the manus measures about 25^{mm} in length; and 14^{mm} in vertical diameter at the base.

This animal could not have been more than five or six feet in length. The known remains are from the same horizon as those above described.

All the specimens described in the present article were found by Mr. J. B. Hatcher, of the U. S. Geological Survey, and the writer's able field assistant in paleontology.

The fossils here described, and others from the same horizon, seem to prove conclusively that the Potomac formation in its typical localities in Maryland is of Jurassic age, and lacustrine origin. There is evidence that some of the supposed northern extensions of this formation, even if of the same age, are of marine, or estuary origin.

Yale College, New Haven, Conn., Dec. 23, 1887.

Art. VII.—*Notice of a New Fossil Sirenian, from California;* by O. C. Marsh.

In exploring a Tertiary deposit in California a few years since, the writer obtained several teeth of a large mammal, very distinct from anything hitherto discovered in this country. Other specimens were subsequently secured, and with them, a number of vertebræ, apparently pertaining to the same animal which is described below. The associated vertebrate fossils were a large edentate (*Morotherium*), a mastodon, a camel, and one or more extinct species of the horse, all indicating the Pliocene age of the strata in which they were entombed.

Desmostylus hesperus, gen. et sp. nov.

The remains known of the present species indicate an animal about fifteen feet (M. 4·5) in length, and of robust proportions. The most characteristic parts preserved are the molar teeth, which are composed of a number of vertical columns, closely pressed together, and in adult animals, firmly united at their bases. These columns are thickly invested with enamel, which is rugose externally. Inside the enamel, is a body of dentine, in which there is a central cavity.

In immature teeth, the columns are nearly round, and loosely united, but as they increase in size, they press together, and become more or less polygonal in cross section. Before being worn, they have their summits smooth and convex, but after some use, the center of each column presents a rounded elevation, well shown in the figures below. This is due to the harder material forming the walls of the central cavity. As this apex is removed by further wear, the cavity is reached, and this central opening increases in size as the tooth is shortened by attrition.

FIG. 1. FIG. 2. FIG. 3.

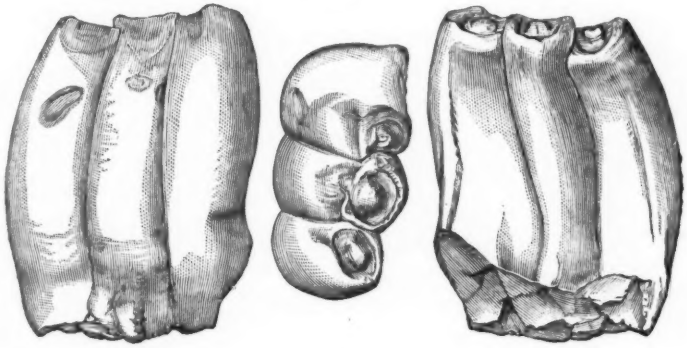


FIGURE 1. Part of tooth of *Desmostylus hesperus*, Marsh; end view.
FIGURE 2. The same specimen; seen from above.
FIGURE 3. The same specimen; inner surface.
All the figures are natural size.

The specimen figured is apparently the posterior portion of a molar tooth. The three columns shown are much smaller than the average, not half as large as some others found with them, and probably belonging to the same individual. The number of columns in a single tooth is uncertain, but there are

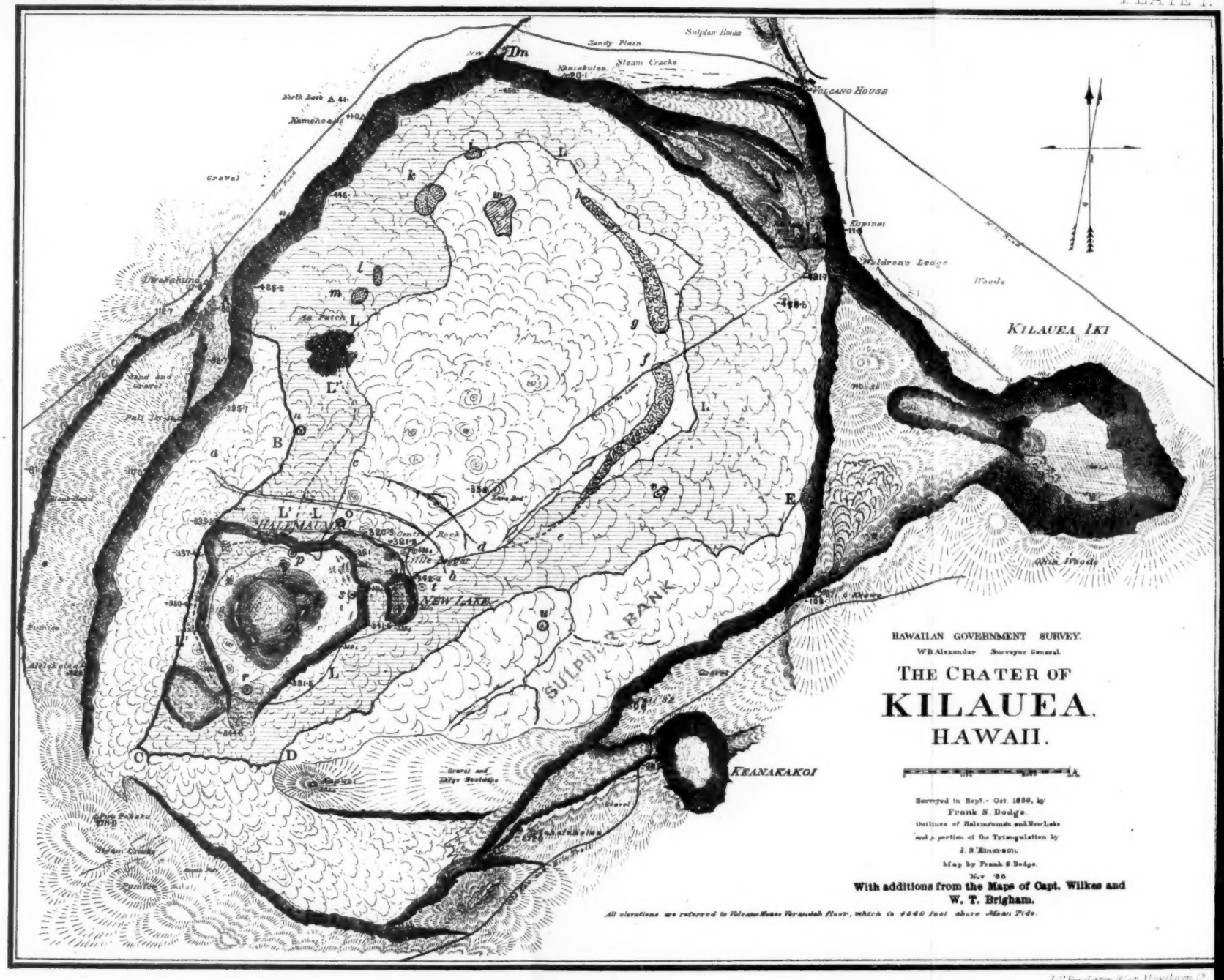
indications of at least twelve or fifteen, and perhaps more. There were both upper and lower molar teeth of similar structure, but the rest of the dentition is unknown.

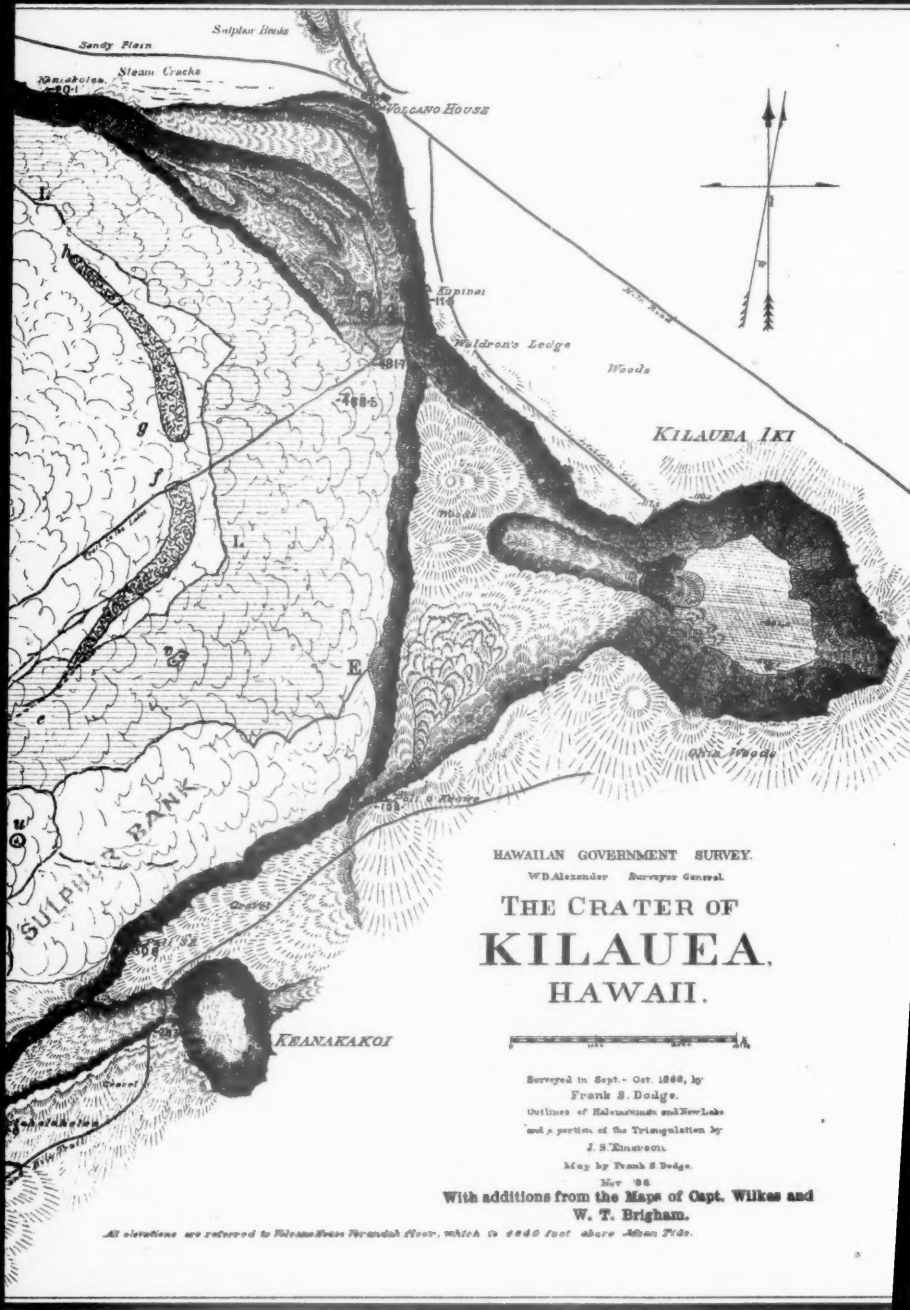
One of the best preserved specimens found with these teeth is a lumbar vertebra, which is noticeable for the extreme flatness of its articular surfaces. The sides of the centrum meet below, forming an obtuse median keel. The centrum of this vertebra has a length of 89^{mm}; the vertical diameter of the anterior face is 90^{mm}, and its transverse diameter 107^{mm}.

The known remains of this animal are from Alameda Co., California, and are preserved in the museum of Yale College. The type specimen was found by Dr. L. G. Yates.

The nearest affinities of this peculiar Sirenian are probably with *Metataxytherium* of Christol, from the Tertiary of Europe, and its nearest living allies may, perhaps, be found in the genus *Halicore*.

Yale College, New Haven, Conn., Dec. 23, 1887.

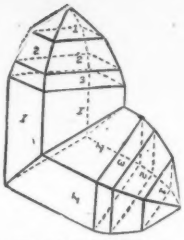

Sandy Plain
Sulphur Banks
Steam Cracks
VOLCANO HOUSE
North Bank
Kamakaoa
Gravel
Kipuhou
Waldron's Ledge
Woods
KILAUEA IKI
Dwarfshrubs
Aa Patch
Sand and Gravel
Pali
HALEMAUMAU
Crater Rock
Little Steam Vent
NEW LAKE
SULPHUR BANK
Gravel and Dike Boulders
KEANAKAKOI
Ohia Woods
HAWAIIAN GOVERNMENT SURVEY.
W.D. Alexander Surveyor General.
THE CRATER OF
KILAUEA.
HAWAII.
Surveyed in Sept.- Oct. 1886, by
Frank S. Dodge.
Outlines of Halemaumau and New Lake
and a portion of the Triangulation by
J. S. Emerson.
Map by Frank S. Dodge.
Nov '86
With additions from the Maps of Capt. Wilkes and
W. T. Brigham.
All elevations are referred to Volcano House Verandah Floor, which is 4040 feet above Mean Tide.


Sulphur Banks
Sandy Plain
Steam Cracks
VOLCANO HOUSE
Kipuna
Waldron's Ledge
Woods
KILAUEA IKI
Olivine Woods
SULPHUR BANK
KEANAKAKOI
HAWAIIAN GOVERNMENT SURVEY.
W.D. Alexander Surveyor General.
THE CRATER OF
KILAUEA,
HAWAII.
Surveyed in Sept.- Oct. 1868, by
Frank S. Dodge.
Outlines of Halemaumau and New Lake
and a portion of the Triangulation by
J. S. Emerson.
Map by Frank S. Dodge.
Nov '68
With additions from the Maps of Capt. Wilkes and
W. T. Brigham.
All elevations are referred to Volcano House Verandah floor, which is 4040 feet above Mean Tide.

LATE I.

s and

arson & Son, New Haven, Ct.



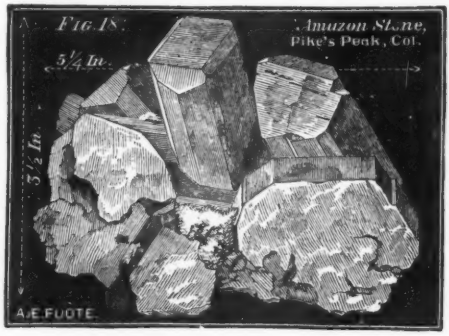
Twin Crystal Zircon.

A. E. FUOTE, M. D.,

No. 1223 BELMONT AVENUE,

PHILADELPHIA, PA.

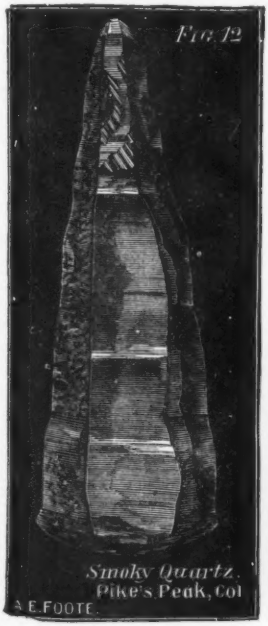
Copies of Naturalist's Leisure Hour, 32 pages, given free on application. If stamp is enclosed, the subscriber's edition, on heavy paper, is sent.



Please state in what Department of Science you are specially interested.

Scientific and Medical Books, Minerals,

And other objects of NATURAL HISTORY.



Largest Stock of Scientific Books in America.

Largest Stock of Minerals in the World.

BECKER BROTHERS,

No. 6 Murray Street, New York,

Manufacturers of Balances and Weights of Precision for Chemists, Assayers, Jewelers, Druggists, and in general for every use where accuracy is required.

April, 1871.—[tf.]

PUBLICATIONS OF THE

JOHNS HOPKINS UNIVERSITY.

I. American Journal of Mathematics. S. NEWCOMB, Editor, and T. CRAIG, Associate Editor. Quarterly. 4to. Volume VIII in progress. $5 per volume.

II. American Chemical Journal.—I. REMSEN, Editor. Bi-monthly. 8vo. Volume VIII in progress. $3 per volume.

III. American Journal of Philology.—B. L. GILDERSLEEVE, Editor. Quarterly. 8vo. Volume VII in progress. $3 per volume.

IV. Studies from the Biological Laboratory.—Including the Chesapeake Zoölogical Laboratory. H. N. MARTIN, Editor, and W. K. BROOKS, Associate Editor. 8vo. Volume III in progress. $5 per volume.

V. Studies in Historical and Political Science.—H. B. ADAMS, Editor. Monthly. 8vo. Volume IV in progress. $3 per volume.

VI. Johns Hopkins University Circulars.—Containing reports of scientific and literary work in progress in Baltimore. 4to. Vol. V in progress. $1 per year.

VII. Annual Report.—Presented to the President by the Board of Trustees, reviewing the operations of the University during the past academic year.

VII. Annual Register.—Giving the list of officers and students, and stating the regulations, etc., of the University. *Published at the close of the Academic year.*

Communications in respect to exchanges and remittances may be sent to the Johns Hopkins University (Publication Agency), Baltimore, Maryland.

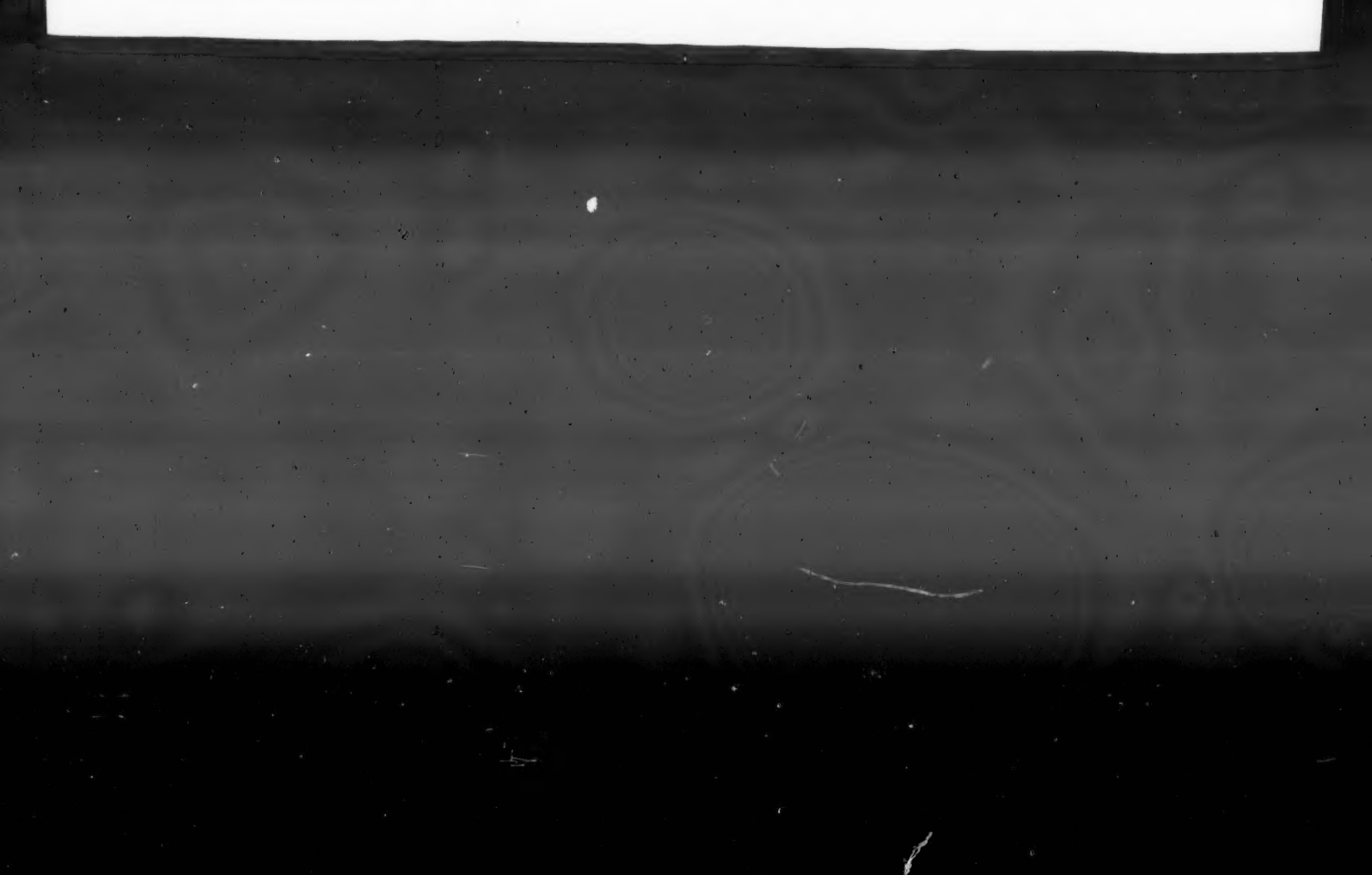
MINERALS

Sold, Bought and Exchanged.

Address **L. STADTMULLER,**

New Haven, Conn.

References: Prof J. D. Dana and Prof. G. J. Brush.



GEORGE L. ENGLISH & CO.,

DEALERS IN

MINERALS.

1512 Chestnut Street, Philadelphia, Pa.

Colleges and Private Collectors will find our Stock Exceptionally Fine and Complete.

Rare Species and Unique Forms a Specialty.

The following species will suggest the character of our stock:

MINIUM, MICROLITE, ALEXANDRITE,
COSALITE, CROCOITE, AMALGAM,
COLORADOITE, ENDLICHITE, COLEMANITE,
PHENACITE, MONAZITE, NAGYAGITE.
BEMENTITE (Just described),
HOLLOW QUARTZ, (Dec. A. J.),
Finest lot English CALCITES ever imported.

Foreign Minerals, personally selected abroad, now arriving
One of the Largest and Finest American Collections now being sold at retail.

Minerals for Technical Purposes.

Correspondence Solicited.

GEO. L. ENGLISH & CO., Dealers in Minerals,
1512 Chestnut Street, - - Philadelphia, Pa.

CONTENTS.

Page.

ART. I.—Speed of Propagation of the Charleston Earthquake; by S. NEWCOMB and C. E. DUTTON 1

II.—History of the changes in the Mt. Loa Craters; by J. D. DANA. Part I. Kilauea. (Plate I). 15

III.—Analysis and Composition of Tourmaline; by R. B. RIGGS 35

IV.—Different types of the Devonian System in North America; by H. S. WILLIAMS 51

V.—Law of Double Refraction in Iceland Spar; by C. S. HASTINGS 60

VI.—Notice of a New Genus of Sauropoda and other new Dinosaurs from the Potomac Formation; by O. C. MARSH 89

VII.—Notice of a New Fossil Sirenian, from California; by O. C. MARSH 97

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics.—Decomposition of the Hydrides of the Halogens by Light in presence of Oxygen, RICHARDSON, 73.—Influence of Liquid water in promoting the decomposition of Hydrogen chloride, ARMSTRONG, 74.—Concentration of Solutions by Gravity, GOUY and CHAPERON, 75.—Percentage of Oxgen in the Air, HEMPEL: Constitution of Selenous Acid, MICHAELIS and LANDMANN: Indexing of Chemical Literature, 76.—Mechanical Equivalent of Heat, DIETERICI: Radiation in absolute measure, BOTTOMLEY: Maximum of Light Intensity in the Solar Spectrum, MENGARINI, 77.—Relation of the wave-length of light to its intensity, EBERT: Brief notice of a paper by Mr. Hallock, SPRING, 78.—Lessons in Elementary Practical Physics, STEWART and GEE, 79.

Geology and Natural History.—Communication by Raphael Pumpelly, 79.—Geological history of the Swiss Alps, 80.—Gradual variation in intensity of metamorphism, 82.—Mission Scientifique du Cap Horn, 83.—The American Geologist: Geology and Mining Industry of Leadville, Colorado, S. F. EMMONS: Fifteenth Annual Report on the Geological and Natural History Survey of Minnesota, N. H. WINCHELL, 84.—New York Paleontology: Annual Report of the Geological Survey of Pennsylvania: Fossil Mammals from the White River formation contained in the Museum of Comparative Zoology, W. B. SCOTT and H. F. OSBORN, 85.—Diatomaceous Earth in Nebraska: The Upper Beaches and Deltas of the Glacial Lake Agassiz, W. UPHAM; Supposed diamonds in a Meteorite: Cryptolite: Grundriss der Edelsteinkunde, P. GROTH: Rivista di Mineralogia e Cristallografia Italiana, R. PANEBIANCO: Catalogue of all recorded Meteorites, O. W. HUNTINGTON, 86.—A chapter in the History of Meteorites, W. FLIGHT: Das pflanzenphysiologische Praktikum, DETMER, 87.

Miscellaneous Scientific Intelligence.—Proceedings of the Colorado Scientific Society: Relative Proportions of the Steam Engine, W. D. MARKS: Modern American Methods of Copper Smelting, E. D. PETERS, 88.

Obituary.—FERDINAND VANDEVEER HAYDEN, 88.